FEBRUARY • 1948

VOLUME XIX NUMBER 5

the Petroleum Engineer

...ds for Operating Men

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Mar. 24-26—NGAA, annual meeting, Texas Hotel, Fort Worth, Texas.
Mar. 24-26—API, Mid-Continent production division, Broadview Hotel, Wichita, Kans.
Mar. 24-26—Southern Gas Assn, annual meeting, Galveston, Texas.
Apr. 5—Nomads, Louis Sherry's, 50th St. and Park Ave., New York City.
Apr. 5-7—Western Petroleum Refiners Assn, annual meeting, Galvez and Buccaneer Hotels, Galveston, Texas.
Apr. 5-8—Natl Assn Corrosion Engineers, annual meet, Jefferson Hotel, St. Louis, Mo.
Apr. 5-8—Oil Heat Institute of America, meeting and exposition, Coliseum, Chicago.
Apr. 12—Nomads, The Houston Club, Houston, Texas.
Apr. 13-15—Southern Gas Measurement Short Course, Univ. of Okla., Norman.
Apr. 14—Institute of Petroleum, Manson House, 26, Portland Place, London, W. I.
Apr. 14—Nomads, Jonathan Club, Los Angeles, Calif.
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Apr. 19-23—American Chemical Society, 113th national meeting, Chicago, Ill.
Apr. 21-23—National Petroleum Assn, Hotel Cleveland, Cleveland, Ohio.
Apr. 26-29—Am. Assn of Petroleum Geologists, Soc. of Economic Paleontologists & Mineralologists, & Soc. of Exploration Geophysicists, annual meeting, Denver, Colo.
Apr. 28-30—Liquefied Petroleum Gas Assn, annual convention, Kansas City, Mo.
Apr. 28-30—Interstate Oil Compact Commission, Spring meeting, Chicago, Illinois.
May 3—Nomads, Louis Sherry's, 50th Street and Park Avenue, New York City.
May 4-5—AGA, Natural Gas Department, Spring meeting, Rice Hotel, Houston, Texas.
May 6-7—API, Pacific coast production division, Biltmore Hotel, Los Angeles, California.
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May 15-22—International Petroleum Exposition, Tulsa, Okla.
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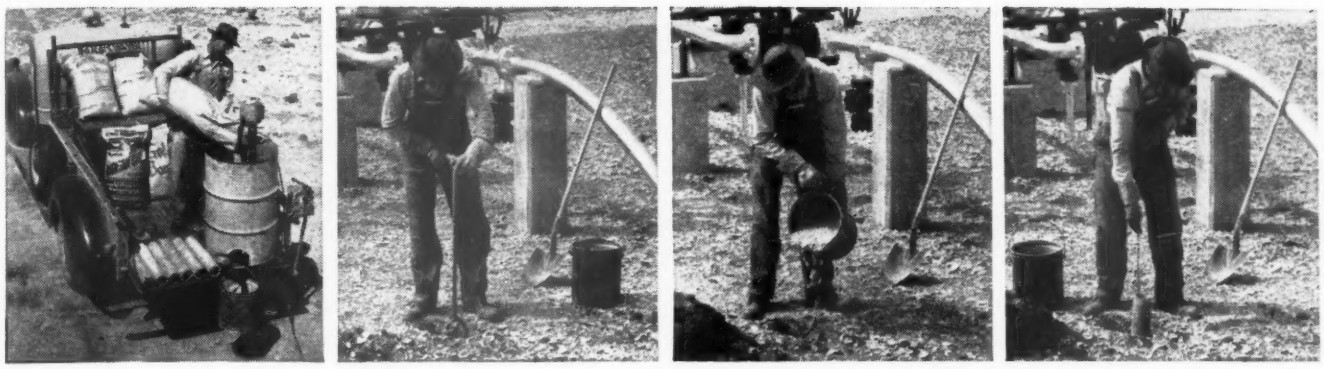

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DEEP WELLS

There are now 461 deep wells in the world that have been drilled to depths greater than 12,000 feet. Of these, 144 were drilled during 1947, and all but 12 within the borders of the United States. A conservative estimate of the total cost of all wells drilled to a depth greater than 12,000 feet since 1935, is one hundred and fifty million dollars. Experience data obtained in a deep well survey, the subject of an article elsewhere in this issue, are too meager to enable one to make any fair assessment of the economic factors involved in the drilling of wells to these great depths. From the data gathered, however, some pertinent observations can be made on deep drilling operations in general.

Of 35 new fields or new productive sands discovered in 1947, ten, or almost one-third, were below the 12,000-ft mark. Aside from the discovery of new oil reserves, deep wells yield other values, which though less tangible, are nevertheless important. Geological information is developed that plays an important role in providing data for planning subsequent drilling operations. Valuable experience is also acquired in overcoming difficulties peculiar to deep drilling operations, an item that should lead to a reduction of costs in subsequent development operations.

Unit cost figures in deep drilling are difficult to arrive at because of the paucity of information and also the lack of uniformity in accounting methods. From the information thus far available, it is difficult or almost impossible to determine how much the drilling cost per foot increases with depth in these very deep wells. So far as can be determined, deep drilling costs in the United States in 1947 were 13½ per cent greater than in 1936. Thus it would appear that the rate of cost increase with depth may not be so great as is generally believed.

Deep well drilling costs do vary within wide limits. In Louisiana, for example, a well was drilled to a depth of more than 12,000 feet at a cost of $87,000. The average cost of wells of this depth from the data available is $363,000 or more than four times as great. This wide variation is not too surprising, when the different underground conditions likely to be encountered are considered. There will always be a substantial variation in costs, the amount depending on the drilling area.

Core drilling and mud materials are items that may swell the cost of deep drilling in previously untested areas. More than two tons of cores were taken while drilling the well that presently holds the world record for depth. It reached a depth of 17,823 feet and is estimated to have cost one and a half million dollars.

The time element in itself is important. For each day spent on the well the cost of drilling crews and equipment have to be covered. If a fishing job occurs and the time to clean it up is prolonged, the cost of the well can take an abrupt upward trend.

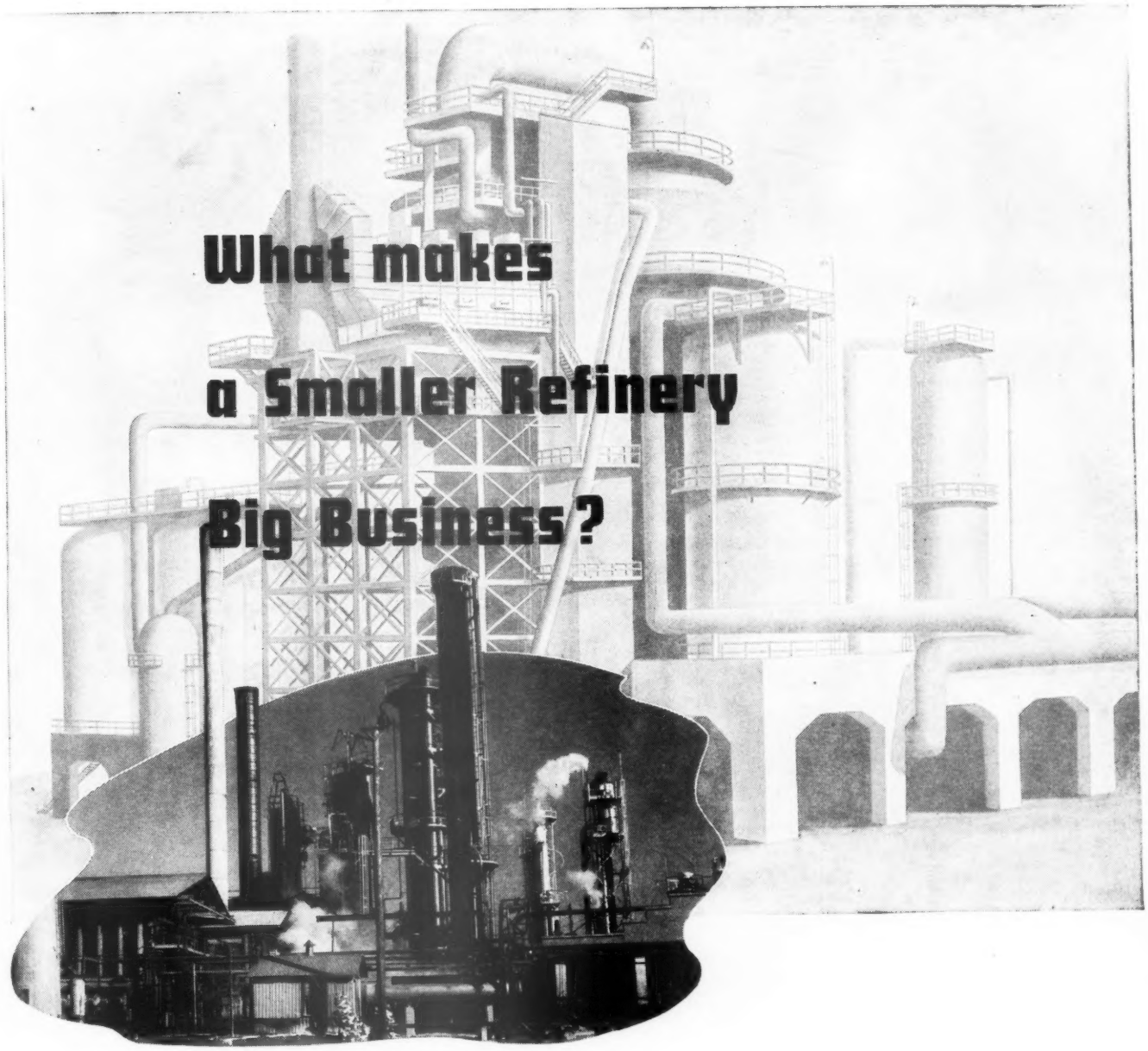
Drilling 144 wells in a single year to a depth of more than 12,000 feet is evidence of the efforts the industry is putting forth to uncover new reserves and to develop a greater producing capacity to meet anticipated future demand.

CONFLICTING OPINION

Petroleum is an important national resource in time of peace. It is even more important in war; both world wars have accentuated this fact. Apprehension over the possibility of a third world war is spotlighting its importance now. Petroleum, being an essential sinew of war as well as a national resource, is being projected more prominently than ever before into the realm of world politics. It has thus become a subject of Congressional scrutiny. Committee hearings have been and are being held on petroleum. At these a barrage of conflicting opinion and suggestions have been and are being offered on national oil policy and related problems.

Some of the most violently conflicting opinion is within the industry itself. This is not surprising in view of present world conditions, for it is hard to maintain a normal viewpoint, particularly with regard to oil because of its importance in world affairs. Indeed, it might be asked whether a normal viewpoint on oil should be expected. Laboring under the scare of the imminence of a third world war, one's viewpoint is likely to be quite different from what it would be were there real assurance of a long period of world peace. In these circumstances and in view of present unpredictable world conditions, the best interests of the oil industry in general and the domestic oil industry in particular are given only secondary consideration.

It would do much toward sounder thinking if the opinions and suggestions put forth were backed up by supporting data on which opinions are based. It makes a decided difference whether one is thinking in terms of national interest, international interest, or in terms of only the domestic industry itself. Perhaps if this were borne in mind, much of the conflicting opinion within the industry now rampant would be more nearly reconciled.—K.C.S.



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SCANNING WASHINGTON'S OIL HORIZON

By MILBURN PETTY

WASHINGTON—For a long while, many leaders of the industry, the Truman Administration, and Congress have felt the need for a national oil policy, although there has been little agreement on the elements it should contain.

Now, with trouble in the Middle East "jeopardizing" American oil development there, according to Defense Secretary Forrestal, and shortages at home making the people more oil-conscious than ever before, it is probable that something will be done along this line.

Some of President Truman's advisers favor appointment of a presidential commission, like the Baruch Rubber Committee in 1942, to study and make recommendations on all aspects of the petroleum situation such as synthetic fuels, development of accessible foreign areas, and provision for a strong domestic industry.

In Congress, support is gaining for a joint committee on fuel policy that would study all sources of energy with particular emphasis on inter-fuel competition and "superior" uses of each one.

Undoubtedly it would be better for all concerned if a competent group were to be named to make an impartial study of the oil situation, or perhaps fuels, generally, rather than hasty legislative action to embargo oil exports, prohibit new oil burner installations, ration scarce products, regulate "end use" of oil and gas, and other control ideas proposed in the near-hysteria that has developed in Congress over the oil and gas shortages this winter.

Typical of the congressional attitude is a recent report by the House Interstate Commerce Committee, headed by Congressman Wolverton (Rep., N. J.). This is a traditionally conservative committee, which in times past has blocked several federal oil control bills. Wolverton, the chairman, was a member of the original Cole Oil Committee set up in 1934.

This committee's report criticized industry leaders for their optimism last summer over the oil supply outlook, quoting chapter and verse on some of them. The committee's resentment at what they regard as lack of action against oil shortages by the industry and the government is evident in this statement from their report:

"The committee does not believe that we are forced to accept the panaceas which so far have been offered to us by the government and by the industry; namely, the cheerful acceptance by the consuming public of the inevitability of these tight situations; the leaving to the industry to work out without governmental interference this problem which for some time now they have assured us would not arise and the solution to which they so manifestly so far seem unable to reach; or acquiescence to the superficial remedy suggested by allocating or rationing available supplies without maximum effort to effectuate a real cure through bringing supplies and demand in line."

●

The Middle East crisis has given impetus to several alternative sources including synthetics. Also, it has prompted consideration of drastic steps to protect American oil interests in that area. For example, the Navy is considering taking an interest in Arabian-American Oil Company either by acquiring stock, long-term oil purchase, or outright purchase of 8 or 10 billion barrels of Aramco's reserves.

On synthetics, Interior Secretary Krug has presented to Congress a $9 billion program to provide capacity of 2,000,000 bbl a day of liquid fuels within 5 or 10 years, starting with the construction of several commercial-size plants as soon as possible. (This is the program agreed upon last summer by the secretaries of Army, Navy, and Interior and reported in this column last August.)

First reaction from the oil industry was that, if an emergency threatens, more oil can be obtained—quicker—by making steel available to the industry for drilling and development work. Commercial development of synthetic fuels should come along gradually, over a period of years, and not under a condition of war urgency at "fantastic" cost. Also, it is uneconomic to produce synthetic fuels from gas or coal for purposes which could be served more efficiently by gas or coal being burned directly.

Krug replied to criticism with this summation to Congress:

"First of all, the government won't do any experimental work on synthetics that the industry is willing to do. Second, we don't plan that the government will do any part of the $9 billion program which the industry will do—but the government must take the leadership. Third, I am recommending the construction of three plants—not a $9 billion synthetic construction program right away. These three plants would cost about $300,000,000. After they are built and the processes are perfected, I hope that industry will go ahead with the program and take over most of what must be done. But this program is so vitally important, that the government should do all of it, if it has to. However, I feel that we will get fine cooperation from the industry."

Proposals to spend millions on synthetics brought the suggestion from J. P. Jones, Bradford, of the Pennsylvania Grade Crude Oil Association, that a very small fraction of this expenditure would, if spent on secondary recovery research, produce much more natural petroleum.

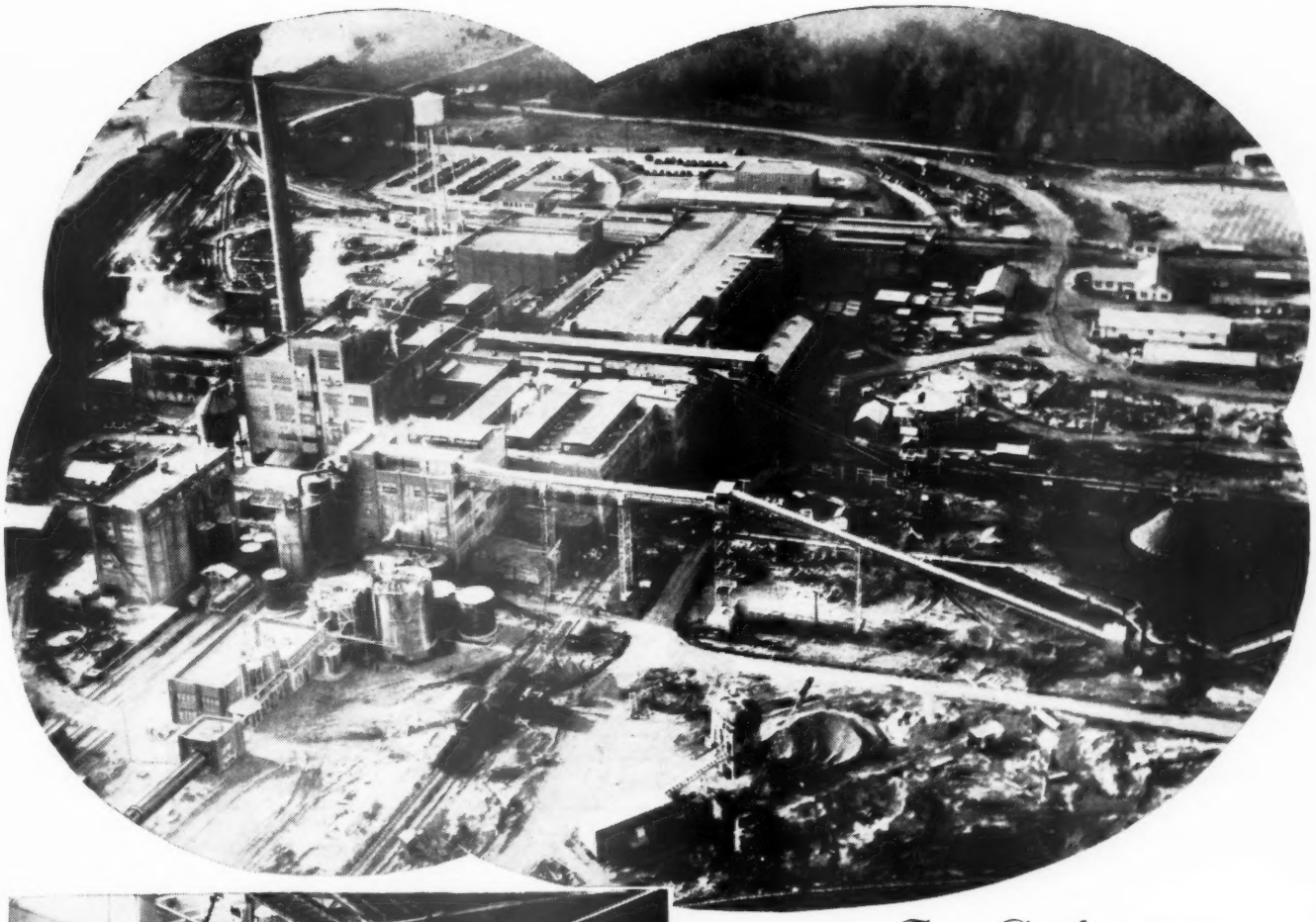
Meanwhile, Congress is expected to enact the bill doubling the Interior Department's authorization for synthetic fuels, making it $60,000,000. In passing the bill, the Senate accepted a committee report that stated, flatly, "it has become increasingly apparent that the United States must turn to synthetic sources to supplement its petroleum reserves."

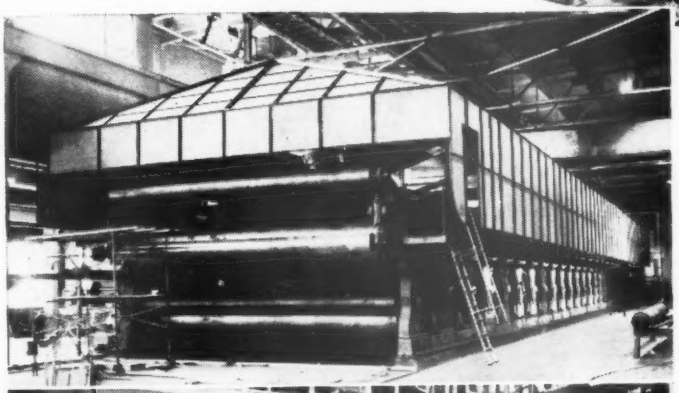
Another idea discussed before congressional committees was the matter of stockpiling oil for emergency. Ralph K. Davies (Ex-PAW) suggested that, with higher crude prices, it might be economical now to import crude for storage in abandoned mines as was considered during the war. E. DeGolyer, geologist, disagreed with this, suggesting, instead, trading imported crude for oil reserves in place in the United States.

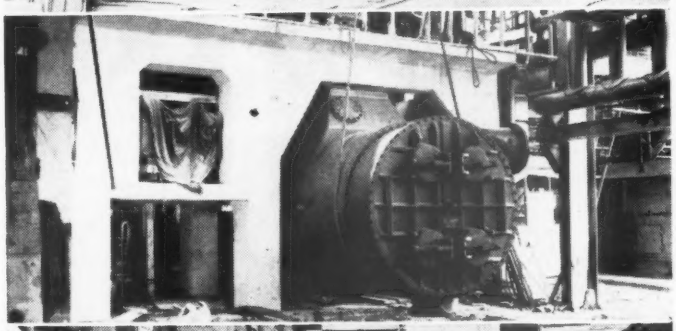
Tidelands oil is also figuring in discussions of national policy with both the industry and the military insisting that prompt development of these oil-rich areas is imperative. Most of the industry, however, believes that this could be encouraged by enactment of the states rights tidelands bill returning ownership and jurisdiction of these coastal lands to the states. On the other hand, Defense Secretary Forrestal is backing the federal tidelands bill, which provides for control by the Interior Department. (Provisions are along the lines outlined here last month.)

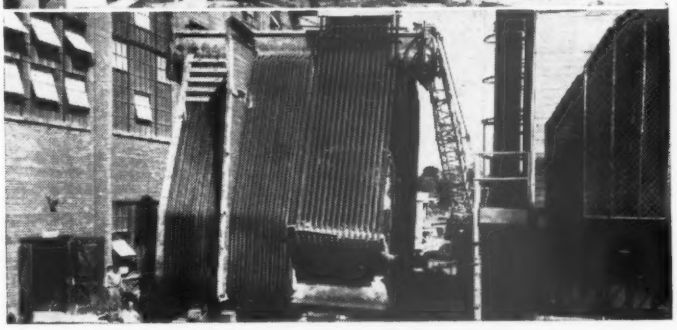
Meanwhile, at a long last, something is being done by the government to provide more steel for the domestic industry. A voluntary steel allocation program is being worked up, with Russell B. Brown (IPAA) chairmanning a National Petroleum Council committee drawing up requirements estimates.

Short range, the oil shortage situation has been dumped into the industry's lap with Attorney General Clark unexpectedly giving a "green light" to the NPC to deal with the petroleum on its own until April 1 (except there must be no price fixing). In the meanwhile, it is up to the Industry to decide whether or not it wishes to come in with a "permanent" program under the new Taft Law allowing voluntary industry agreements.









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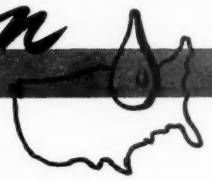
national petroleum situation



By H. J. STRUTH,*
Petroleum Economist

IMPROVED SUPPLY PICTURE. In response to record-breaking demand the industry effected a substantially improved supply picture in January. While demand last month was 7 per cent above January, 1947, supply of all oils was 14 per cent greater than a year ago. Last year there was a net shortage of 450,000 bbl daily; this year, due to all-out efforts to meet demand, net shortage was only 127,000 bbl daily. January demand was 415,000 bbl a day greater than last year, but supply was greater by 738,000 bbl daily.

REFINERS PERFORM MIRACLES. Efforts of refiners to meet stringent fuel oil shortages of the nation's most severe winter are shown by January figures. Runs to stills averaged 5,435,000 bbl daily, nearly 700,000 bbl a day greater than last year. Efficient use of all available equipment and adjustment of yields increased fuel oil output 23 per cent over last year. January output was 456,000 bbl above last year; motor fuel output increased 275,000 bbl daily. Capacity operations helped to alleviate and prevented far more serious shortages of fuels; also increased motor fuel stocks 3,800,000 bbl above last year's level.

DRILLING TRENDS UPWARD. Cold weather and heavy snows in most active areas last month had a retarding effect on drilling operations. Yet, higher oil prices are providing incentive needed to keep all available rigs busy. January wildcat completions were 23 per cent above last year; development drilling was 10 per cent greater. When more equipment is available, drilling operations will show an even more pronounced increase. Arkansas, Kansas, Oklahoma, and Texas continue to lead increased wildcat activity.

IMPROVED STOCK POSITION. Greatly expanded refinery operations in January improved the refined products stock picture. In December, stocks were 4,618,000 bbl below year-end 1946; in January they were 5,596.000 bbl above last year. Crude stocks, January 31, were 1 per cent under last year; representing 40 days supply against 46 days.

*Editor, *The Petroleum Data Book.*

Comparative Statistics, January, 1948

*All figures are computed on a Bureau of Mines' Basis**

	Jan. 1948Ⓟ	Dec. 1947Ⓟ	Jan. 1947	This year to date	Last year to date	Per cent change
Wells drilling	4,500	¶4,540	3,900	4,500	3,900	+15
Total wells drilled§	3,027	3,060	2,653	3,027	2,653	+14
Development wells	2,305	2,355	2,092	2,305	2,092	+10
Oil	1,640	1,563	1,375	1,640	1,375	+19
Gas	207	259	284	207	284	−27
Dry§	458	533	433	458	433	+ 6
Per cent dry	19.9	22.6	20.7	19.9	20.7	− 0.8
Service wells	218	233	150	218	150	+45
Wildcat wells	504	472	411	504	411	+23
Oil	60	52	55	60	55	+ 9
Gas	19	25	10	19	10	+90
Dry	425	395	346	425	346	+23
Per cent dry	84.3	83.7	84.2	84.3	84.2	+ 0.1
Crude supply⊖	174,500	172,890	152,563	174,500	152,563	+14
Daily average	5,629	5,577	4,921	5,629	4,921	
Crude demand‡	175,440	175,290	153,307	175,440	153,307	+14
Daily average	5,659	5,655	4,945	5,659	4,945	
Crude stocks	228,140	229,080	229,432	228,140	229,432	− 1
Days supply	40	41	46	40	46	
Natural gasoline production	12,100	11,470	10,571	12,100	10,571	+14
Daily average	390	370	341	390	341	
Motor fuel production	74,430	75,050	65,904	74,430	65,904	+13
Daily average	2,401	2,421	2,126	2,401	2,126	
Gasoline yield, per cent	39.2	40.2	39.9	39.2	39.9	− 0.7
Motor fuel demand‡	64,745	68,720	60,325	64,745	60,325	+ 7
Daily average	2,089	2,217	1,946	2,089	1,946	
Motor fuel stocks△	98,950	¶89,265	95,094	98,950	95,094	+ 4
Days supply	47	40	49	47	49	
Fuel oil production	74,650	70,030	60,521	74,650	60,521	+23
Daily average	2,408	2,259	1,952	2,408	1,952	
Fuel oil demand‡	92,230	91,980	85,567	92,230	85,567	+ 8
Daily average	2,975	2,967	2,760	2,975	2,760	
Fuel oil stocks	87,940	98,170	89,747	89,940	89,747	− 2
Days supply	30	33	33	30	33	
Refinery still runs	168,480	166,260	146,897	168,480	146,897	+15
Daily average	5,435	5,363	4,739	5,435	4,739	
All refined stocks	269,300	272,300	263,704	269,300	263,704	+ 2
Days supply	43	42	45	43	45	

Supply and Demand—All Oils

	Jan. 1948Ⓟ	Dec. 1947Ⓟ	Jan. 1947	This year to date	Last year to date	Per cent change
Total supply, all oils	192,300	188,812	169,421	192,300	169,421	+14
Daily average	6,203	6,091	5,465	6,203	5,465	
Total demand‡, all oils	196,240	203,712	183,379	196,240	183,379	+ 7
Daily average	6,330	6,571	5,915	6,330	5,915	
Change in stocks (total)	−3,940	−14,900	−13,958	−3,940	−13,958	

Current Crude Oil Prices

U. S. average	$2.61	Louisiana	$2.62
Texas	2.61	Arkansas	2.43
California	2.42	New Mexico	2.40
Oklahoma	2.63	Mississippi	2.42
Kansas	2.62	Illinois	2.76
		Other states	3.15

Basic crude prices:

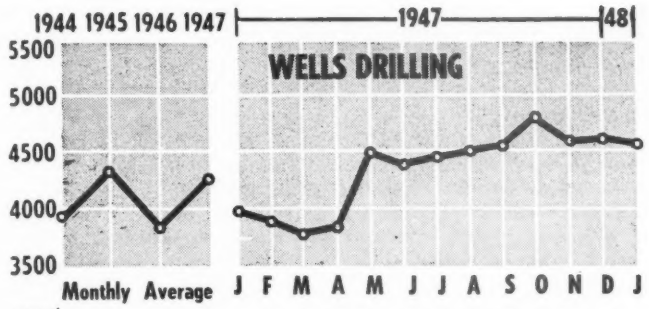
Oklahoma-Kansas (36 gr.)	$2.57
Texas Gulf Coast (36 gr.)	2.80
East Texas	2.65
West Texas (36 gr.)	2.44
California Signal Hill (26 gr.)	2.41
Pennsylvania, Bradford	5.00

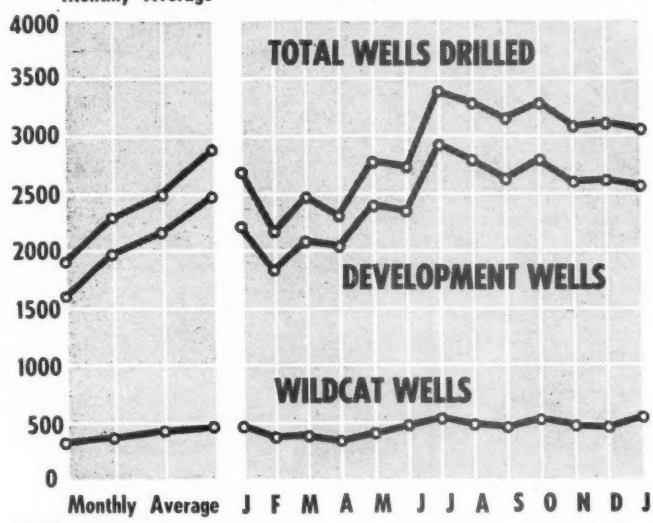
Drilling and Production Statistics by States

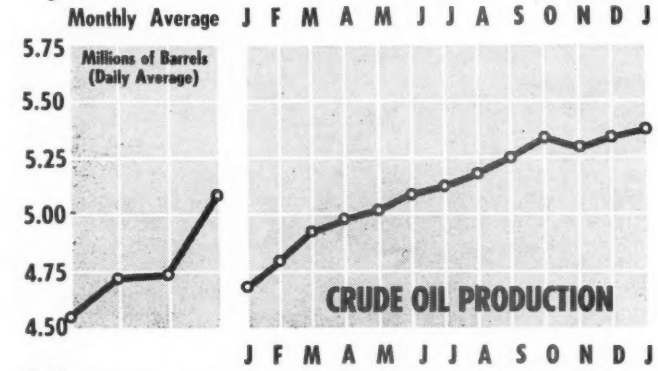
	Jan. 1948Ⓟ	Dec. 1947Ⓟ	Jan. 1947	This year to date	Last year to date	Per cent change
Wells drilled§ (excl service)	2,809	2,827	2,503	2,809	2,503	+ 12
Arkansas	35	26	23	35	23	+ 52
California	216	207	170	216	170	+ 27
Illinois	173	191	166	173	166	+ 4
Kansas	244	269	211	244	211	+ 16
Louisiana	144	165	102	144	102	+ 41
Mississippi	35	44	35	35	35	0
New Mexico	60	69	42	60	42	+ 43
Oklahoma	334	333	349	334	349	− 4
Texas	892	782	765	892	765	+ 17
Other states	676	741	640	676	640	+ 6
Wildcats drilled (incl above)	504	472	411	504	411	+ 23
Arkansas	11	7	5	11	5	+120
California	26	35	25	26	25	+ 4
Illinois	28	41	40	28	40	− 30
Kansas	35	39	29	35	29	+ 21
Louisiana	16	17	20	16	20	− 20
Mississippi	9	6	11	9	11	− 18
New Mexico	3	4	5	3	5	− 40
Oklahoma	84	87	72	84	72	+ 17
Texas	222	166	136	222	136	+ 63
Other states	70	70	68	70	68	+ 3
Daily crude production	5,368	5,327	4,671	5,368	4,671	+ 15
Arkansas	87	87	79	87	79	+ 10
California	935	927	884	935	884	+ 6
Illinois	171	182	193	171	193	− 11
Kansas	292	289	269	292	269	+ 9
Louisiana	475	466	414	475	414	+ 15
Mississippi	115	112	88	115	88	+ 31
New Mexico	125	125	102	125	102	+ 23
Oklahoma	406	413	364	406	364	+ 12
Texas	2,401	2,360	1,958	2,401	1,958	+ 23
Wyoming	134	133	107	134	107	+ 25
Other states	227	233	213	227	213	+ 7

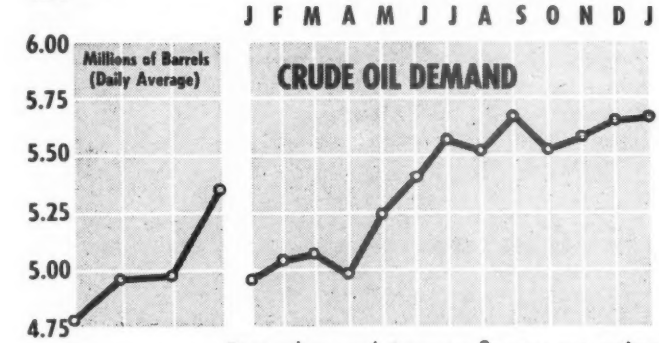
*Unless otherwise stated all figures represent thousands of barrels. Ⓟ–Preliminary. ⊖Includes domestic production and imports.
‡Total demand, including exports. △Includes finished and natural gasoline. ¶Revised.

Preliminary estimates based upon data supplied by American Petroleum Institute, U. S. Bureau of Mines, State Agencies, and other official sources.

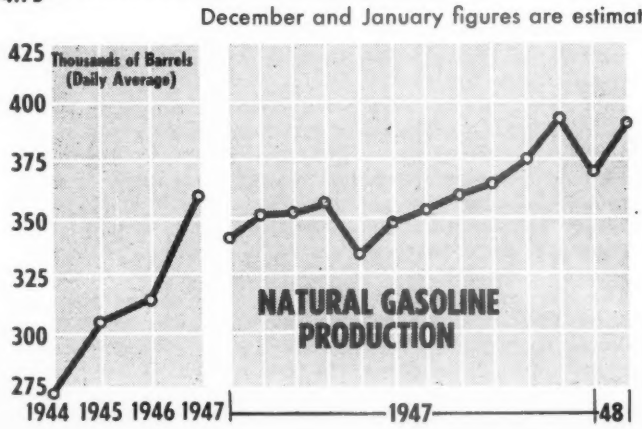


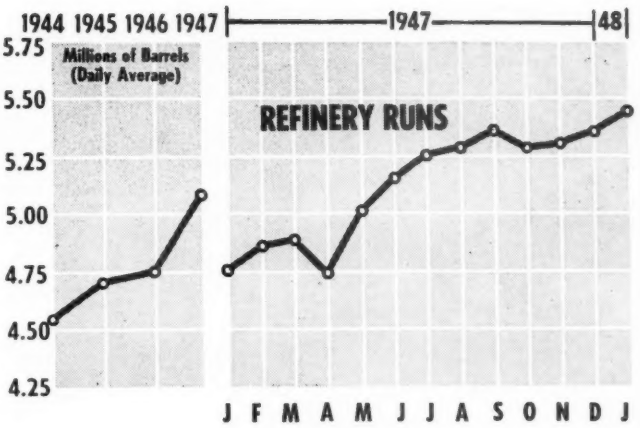


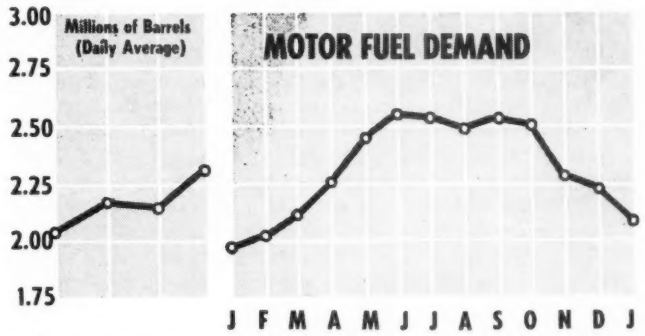


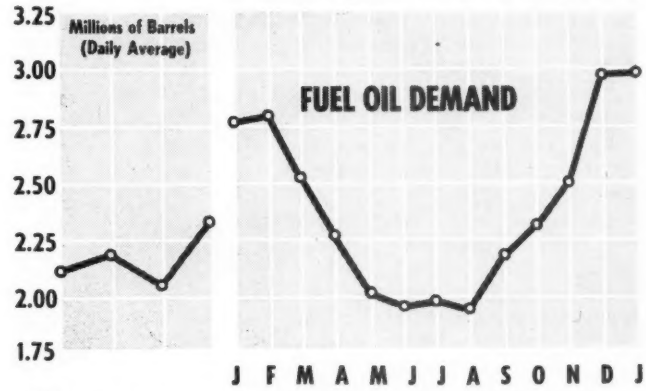


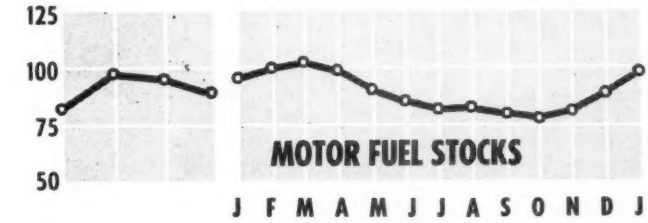
December and January figures are estimates.

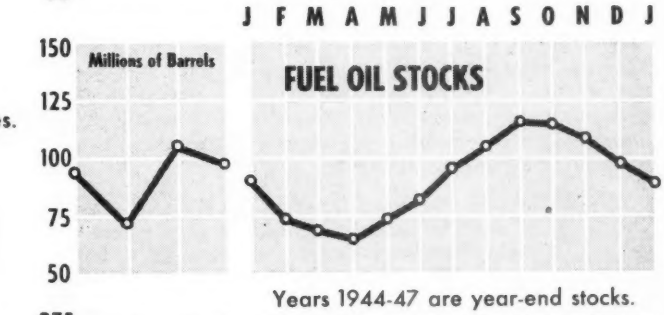




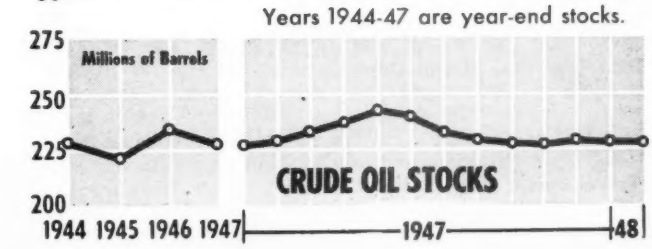








Years 1944-47 are year-end stocks.



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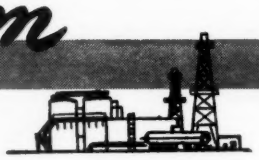

● **PROPOSED TIDELANDS LEGISLATION FILED.** Secretary of Interior Krug has filed with the two Houses proposed legislation designed to implement the recent Supreme Court decision giving the federal government paramount rights to tidelands.

The bill provides no rights or claims to mineral deposits, regardless of how filed in the past, shall be recognized except in accordance with the new act. The president is empowered to withdraw any land in the marginal area from public leasing and to designate it as a mineral reserve of the United States.

The bill denies justification in any contention that substantial equity now exists that would warrant giving any application preferential consideration in issuing oil and gas leases.

In war the federal government can refuse at market price all or any oil and gas produced from the submerged lands. This in effect, according to Secretary Krug, gives the government a continuing option at a fair price ahead of other possible purchasers.

Other sections give the secretary discretion as to leasing, except for lands reserved by the president and in the interest of national security.

Submerged coastal lands not within any known geological structure of a producing oil and gas field, as well as those within, may be leased after competitive bidding to the highest bidder. Leases in untried geological structures may not exceed 64,000 acres.

It was emphasized acreage limitation in general in the proposed act is more generous than under the mineral leasing act, to stimulate exploration and development in water areas, which are more costly and complex than on dry land.

Royalty to be paid both for structure and off-structure leases is not less than 12½ per cent of the amount or value of the oil or gas produced.

It is recommended the United States pay 37½ per cent of income to states within whose boundaries the activities take place, to be used for public roads, parks, or education. The government would pay 52½ per cent of it into reclamation funds of tidewater states.

Major theme of the bill is national defense, with the secretary given right to regulate rate of prospecting and development, and the quantity and rate of production from leases. The secretary is justified in fixing rates without strict regard for conservation or engineering practices. He also may terminate any lease in a national emergency.

● **VENEZUELA SIGNS OIL CONTRACTS.** Royalty contracts yielding more revenue to the Venezuelan government were signed by Creole Petroleum Corporation and all other producers on January 22 in Caracas at the Ministry of Development. In an official announcement from the minister. Dr. Juan Pablo Pérez Alfonzo, it was revealed that the Venezuelan government had proved through its recent auction of royalty oil that higher prices are obtainable at this time. The government royalty in 1948 is estimated at 12,500,000 cubic meters, which will now yield $13,500,000 in additional revenue making the total government oil royalty in 1948 approximately $186,750,000. This arrangement will be more profitable to Venezuela than agreements with individuals. The government will retain, however, its option of trading some of the royalty petroleum for merchandise if it is compelled to do so due to a scarcity of merchandise in Venezuela.

A breakdown of the terms of the new agreements with the producing companies reveals that they will pay an average of $1.08 above the normal price per cubic meter except on the amount already sold in October. The new price for royalty oil begins with November, 1947, production. Bachaquero Zulia is the lowest quality cited ($1.86252 a bbl). The highest is El Roble Guárico ($2.70894 a bbl). There are in all a total of 20 prices quoted. All prices may go up according to the market but they may not sink below those guaranteed in the agreement.

● **CANADA'S IMPORT REDUCTION CONTINUES.** Canada's voluntary reduction in imports of fuel oil from the United States, which has been in effect since January 1, will be continued until the end of April, the Department of Commerce announced through its Office of International Trade.

This action is the result of an agreement between the Canadian Government and the Canadian oil industry. Under the terms of the agreement imports from the United States of kerosine, gas oil, and distillate fuel oil (Census Schedule B 5027 and 5030) during the first four months of 1948 will not exceed 50 per cent of the Canadian imports of these fuel oils from the United States during the same period of last year. Total Canadian imports from the United States of these fuel oils during the first four months of 1948 will not exceed 1,320,000 bbl.

● **PETROLEUM EXPORTS REDUCED.** In view of the serious shortage of fuel oils in certain areas of the United States, the Department of Commerce announced it has revised downward the first quarter quota of petroleum products for foreign export from 11,850,000 bbl to 9,650,000 bbl. This represents a reduction of 18.5 per cent in the quota originally established.

In addition, the department announced it would limit licenses for export of petroleum products to exports from those areas of the country where the fuel can best be spared during this emergency period.

The Department of Commerce announced also that a separate quota of gas oil and distillate fuel oil, which has been established for the first quarter for shipments to Japan and the Ryukus, had been drastically reduced from 1,600,000 bbl to 100,000 bbl. It was explained that the difference would be met from oil-producing areas outside the United States.

Following is a table giving a breakdown of the original and revised quotas by petroleum category:

	Original first quarter quota, bbl	Revised first quarter quota, bbl
Aviation gasoline	700,000	700,000
Motor gasoline	5,250,000	4,550,000
Kerosine	900,000	600,000
Gas oil and distillate fuel oil	3,200,000	2,800,000
Residual fuel oil	1,800,000	1,000,000
Total	11,850,000	9,650,000

● **THIEVES USE AERIAL RECONNAISSANCE.** Thieves are now using aerial reconnaissance methods to find their prey in Texas oil fields.

John W. Kelley, chief investigator for the Texas Mid-Continent Oil and Gas Association, has warned Texas oil men that oil field supply thieves are stepping up their activity to take advantage of the current steel shortage and scarcity of materials.

In a recent case it was reported that tools and supplies were spotted in flights over the oil fields and confederates were tipped off on the location of the equipment. Using trucks, the thieves hauled the heavy equipment off to junk yards where "fences" disposed of the stolen property.

Kelley praised recent action by the Wichita County grand jury, which asked peace officers to be on guard against the current increase in theft of oil field equipment.

The jury report also warned that persons selling pipe and supplies at low prices would be suspected of handling stolen property. The grand jury cited the Texas law that provides that any dealer in used oil field equipment must have ample records, bills of sale, and information on place of purchase of all second-hand oil field supplies he handles.

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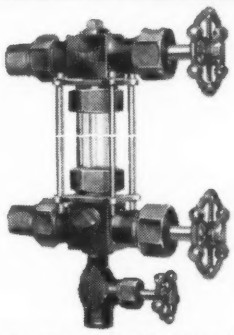
"ALL IRON"

WATER GAGE SET



Extra heavy construction throughout. Body made from special high strength alloy iron, shanks alloy steel and trim stainless steel. Automatic and positive shut-off if glass breaks, valves self-cleaning, dripless drain cock permits gradual blowing off of gage. Conforms with A.P.I.-A.S.M.E. requirements.

The Heavy Duty "All Iron" is one of the complete line of Penberthy gages that meets every liquid level gage requirement.

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For oil field, locomotive type and marine boilers. Water shows black — steam shows white; the water level is unmistakable. U-Bolt construction is strongest and simplest to service. Glass replaced by simply removing nuts on face of gage . . . unnecessary to work between gage and boiler. Conforms with A.S.M.E., Federal and State requirements when used for pressures specified by their respective codes.

This is one of the complete line of Penberthy gages that meet every liquid level gage requirement.

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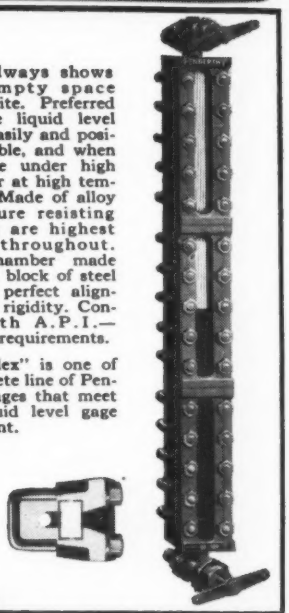
Liquid always shows black—empty space shows white. Preferred where the liquid level must be easily and positively visible, and when liquids are under high pressure or at high temperature. Made of alloy temperature resisting steel and are highest quality throughout. Liquid chamber made from solid block of steel to assure perfect alignment and rigidity. Conform with A.P.I.—A.S.M.E. requirements.

The "Reflex" is one of the complete line of Penberthy Gages that meet every liquid level gage requirement.



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Use the power of steam, air or water under pressure to lift liquids. Being simple jet pumps they have no moving parts and require no lubrication. A variety of models to meet different conditions. Also used as water heaters.

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AUTOMATIC INJECTORS

The accepted method for assuring an uninterrupted supply of feed water to oil field boilers. Penberthy Automatic Injectors will supply feed water to boilers at minimum cost, are quickly and easily installed, reliable under most severe operating conditions, require little attention and no careful handling. Highest quality design and rugged construction.

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Used wherever seepage water accumulates, the Penberthy Automatic Electric Sump Pump and the Penberthy Automatic Drainer (water or steam operated) have demonstrated their superiority in this service. Simple and rugged design—copper and bronze construction throughout.

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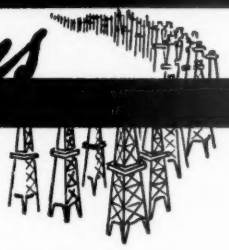
current oil field operations



Exploration wells that have found production.

● **CANADA.** Gulf, Pincher Creek well, Alberta. North of Glacier Park, 15 mi. north of Montana border. DST 5-10,000 MCF gas Madison 11,800 ft.

● **NEW MEXICO.** R. Olsen et al 1 Wimberly 23-25s-37e, Justice pool, Lea. 2820 MCF gas & 25 B cond daily from 4780 ft. New sand.

Amerada 5 Phillips 1-20s-36e, Monument field, Lea. 840 BOPD Paddock 5180-200 ft. New sand.

Gulf 6 Lamunyon 28-23s-37e, Eunice-Monument area, Lea. 41 B 42° oil in 30-min McKee 9348-81 ft.

Delfern 1 Lea-State 8-17s-34e Lea. 111 BOPD 37° San Andres 4673-723 ft.

Petroleum Products Ref. & Prod. 1 Santa Fe, San Juan. 10 BOPD from 3600 ft.

● **WYOMING.** Stanolind 1 Shoshone-Arapahoe SW NE SW 4-1n-1w, Fremont. 21 BOPD Phosphoria 2100 ft.

● **CALIFORNIA.** Standard of Calif. 73-30V, Kettleman Hills field, Kings. 488 BOPD Eocene 12,072-281 ft.

● **KANSAS.** R. L. Williams 1 Soeken SE SE SW 30-20-11w Barton. 994 BOPD 47° Arbuckle 3381-94 ft.

L. Stout & E. Wahl 1 Wm. Livengood SW NE SW 3-1-15e Brown. 85 BOPD Hunton 2605 ft.

Malland Drlg. & Westgate-Greenland 1 Henry Burk CN½ NE SE 7-18-1w McPherson. DST 1 BOPH Chat 2786 ft.

C. E. Ash 1 Wendel-A SW SW NW 16-19s-10w Rice. 30 BOPD from 3325-57 ft.

E. H. Adair et al 1 Corbett 25-29s-5e Butler. 12 BOPD Bartlesville 2813-36 ft.

Skelly 1 Wendel "A" SW SW NW 16-19-10w Rice. 30 BOPD Arbuckle 3357 ft.

Shallow Water Ref. 2 Nunn C NE NE 27-21-34w Nunn pool, Finney. 635 BOPD Marmaton 4370 ft. New sand.

Westgate-Greenland 1 Burk NW NE SE 7-18-1w McPherson. 169 BOPD Mississippi chat 2786 ft.

● **ARKANSAS.** G. H. Vaughn 1 Annie Smith C SE SE 18-16s-17w Union, 54-min DST 645 ft oil Smackover 6320-43 ft.

● **OKLAHOMA.** Magnolia 1 Bull NW NW NE 16-3-2w, N. Antioch pool, Garvin. DST 1 MMCF gas daily, 20 BOPH 50.5° First Bromide 6327-41 ft. New sand.

C. L. Hester & W. H. Potterf 1-A Ferguson NE NW NW 8-7n-8e Seminole. 100 BOPD Booch 2936-67 ft.

Shell 1 Indian CNW SE 30-6n-11w, Caddo. 2-hr DST 150 ft 15° oil dolomite 2695-725 ft.

Ralph Harper 1 Grimes NE NW NE 21-1s-10w Cotton. Oil from 2438-48 ft.

Flynn 1 Jones SE SE NW 18-17n-18e Creek. Swb 2 BOPH 15° from 3230-45 ft.

J. Droppleman 3 Caesar SW NW SW 21-6n-6e Konawa pool Seminole. 75 BOPD Thurman 2500-25 ft. New sand.

Skelly 1 Chapman Ballard NE NW NE 25-4-3w, Garvin. 207 B oil 12 hr Bromide 7637 ft.

● **MONTANA.** Texas 1 Manion SE SW SE 5-11n-30e Musselshell. 200 BOPD 34° Kibbey sandstone 4550 ft.

● **LOUISIANA.** Texas 1 Lottie Ld. & Dev. Co. 25-6s-8e. Point Coupee. 190 BOPD 53° from 10,188-10,228 ft. 165 BOPD 48.5° from 9097-116 ft.

Magnolia 1 McPherson 26-5s-8w Beauregard. DST 47 B cond 55° daily 8896-902 ft.

American Liberty 1 Cleve Dixon sec 12, twp 16, Franklin. Oil from Tuscaloosa 3644-58 ft.

Hunt 1 Delta Lbr. 6-4n-5e Catahoula. 145-165 BOPD from 5506-12 ft.

Kenneth Meredith 2 South Coast Corp. 34-15s-19e, Raceland field, LaFourche. 150 B 50° cond daily 10,085-91 ft. New sand.

Continental 7-A Fee 57-11s-6e, St. Martinville field, St. Martin. 95 BOPD 25.7° from 4000-12 ft. New sand.

● **KENTUCKY.** R. Alworth et al 1 Loving 1-K-25 Hopkins. 1-hr DST gas & oil Hardinsburg 2318-30 ft.

● **MISSISSIPPI.** Gulf 1 L. L. Majors 29-6n-1w Jones. Pumping 214 BOPD 31.2° from 12,011-13,082 ft.

● **TEXAS.** Continental 1 C.P. Miller, Montague. 248 B 41° oil oil in 7 hr conglomerate 6190-204 ft.

Byrd & Delaney 1 Bount, Quirk survey, San Augustine. 1500 MCF gas, 5-10 BOPD Pettit 8530-70 ft.

Gulf 1 J. P. Bevil, Sr. et al, Sabine Tram field, Newton. 100 BOPD 38° from 7366-70 ft. New sand.

A. R. Dillard 1-B Walker, blk 189, Montague. 95.47 B oil in 12 hr Strawn 4948-65 ft.

Gulf 1-A-E Hattie Connell, sec 26, blk B-22, Crane. 180 B oil in 8 hr Silurian 8355-65 ft.

Cities Service 1 Schlittler, sec 1648, TE&L sur, Throckmorton. 20 BOPH 39.6°, 2500 MCF gas daily Caddo 3740-53 ft.

Placid 1 W. E. Forrester, N. Nelson sur A-963 Denton. 90 BOPD from 1602-12 ft.

Sinclair Prairie & Continental 1 Gronow, L. F. Fisch sur A-283 Montague. 127 B oil 14 hr Strawn 4079-89 ft.

Tide Water 1 Guaranty Title & Trust, Nueces. 192 BOPD 45° Frio 11,160-70 ft.

F. M. Manning 1 Atkinson, blk 961, TE&L sur, Throckmorton. 177 BOPH Mississippi 4476-94 ft.

Ungren & Frazier et al 1 Bartlett, sec 43, blk 2, SPRR sur, Jones. 176 B oil 7½ hr Swastika 3230-42 ft.

Star 2 Walter-Buckler, N. Williams sur A-920, Stephens. 175 BOPD 4495-502 ft.

Sun 1 Arledge, sec 261, blk 1-A, HT&C sur, Coke. DST 1470 ft oil Marble Falls 6602-20 ft.

L. W. Barrett et al 1 McCall, J. G. Cox sur 163, Montague. 1-hr DST 70 ft oil Strawn 5289-96 ft.

Sinclair Prairie 1-155 University, sec 24, blk 13, W. Shafter Lake pool, Andrews. 2½-hr DST gas & 24 B oil Wolfcamp 8395-415 ft. New sand.

Coastal Ref. W. D. Kennard 1 Luis Pena, Tract 151, Porcion 38, Starr. DST 1150 ft 44.6° oil from 4364-71 ft.

Nu Enamel 1 R. L. Morrison, blk 465, TE&L sur, Young. 129 BOPD 43° Mississippi 4632-51 ft. New sand.

J. H. Snowden et al & L. H. Freedman 1 Wright, blk 294, BBB&C sur, Throckmorton. 192 BOPD Mississippi 4745-84 ft.

Transgulf 2 Mason, Humble field, Harris. 30 BOPD 19° from 785 ft. New sand.

Phillips 5-M University, sec 31, blk 13, Andrews. 100-min DST 75 BOPH Ellenburger 10,350-80 ft.

Humble 1 J. A. Lutrick, 14-D8-PSL, Hale. 270 B oil 4½ hr Pennsylvanian 7908-87 ft.

Gulf 1 H. H. Cox, S. Sloan A-3389 sur, Crockett. 784 BOPD 26.2° Upper Permian 884 ft.

Sinclair & Continental 1-A W. T. Minor, C. C. Milne sur, Montague. DST 1290 ft oil conglomerate 6184-94 ft.

H. L. Hunt & Sohio 1 Irl Favor, sec 50, blk 21, T&P sur, Nolan. 4 BOPH Ellenburger 6147-93 ft.

Continental & Sinclair-Prairie 1 Miller, sec 21, Montague. 336 B oil 12-hr Bend conglomerate 6190-204 ft.

Texas & American Republics 2 Rice Institute, C. Stewart sur, Hardin. Oil from Wilcox 9025-37 ft.

Texas 2 Schilling, Jergins field, Chambers. 183 BOPD 36.1° Marginulina 6395-99 ft. New sand.

Holly Dev. 1 George Stanchos. J. Kelly sur, Dewitt. 15-min DST 340 ft 35.7° oil from 7599-604 ft.

Texas 1 Broadway, Blackfoot pool, Anderson. 25 BOPH Glen Rose 8972-92 ft. New sand.

Atlantic 1 F. O. Maston, labor 15, league 132, Cochran. 42 BOPD 27° San Andres 4950-050 ft.

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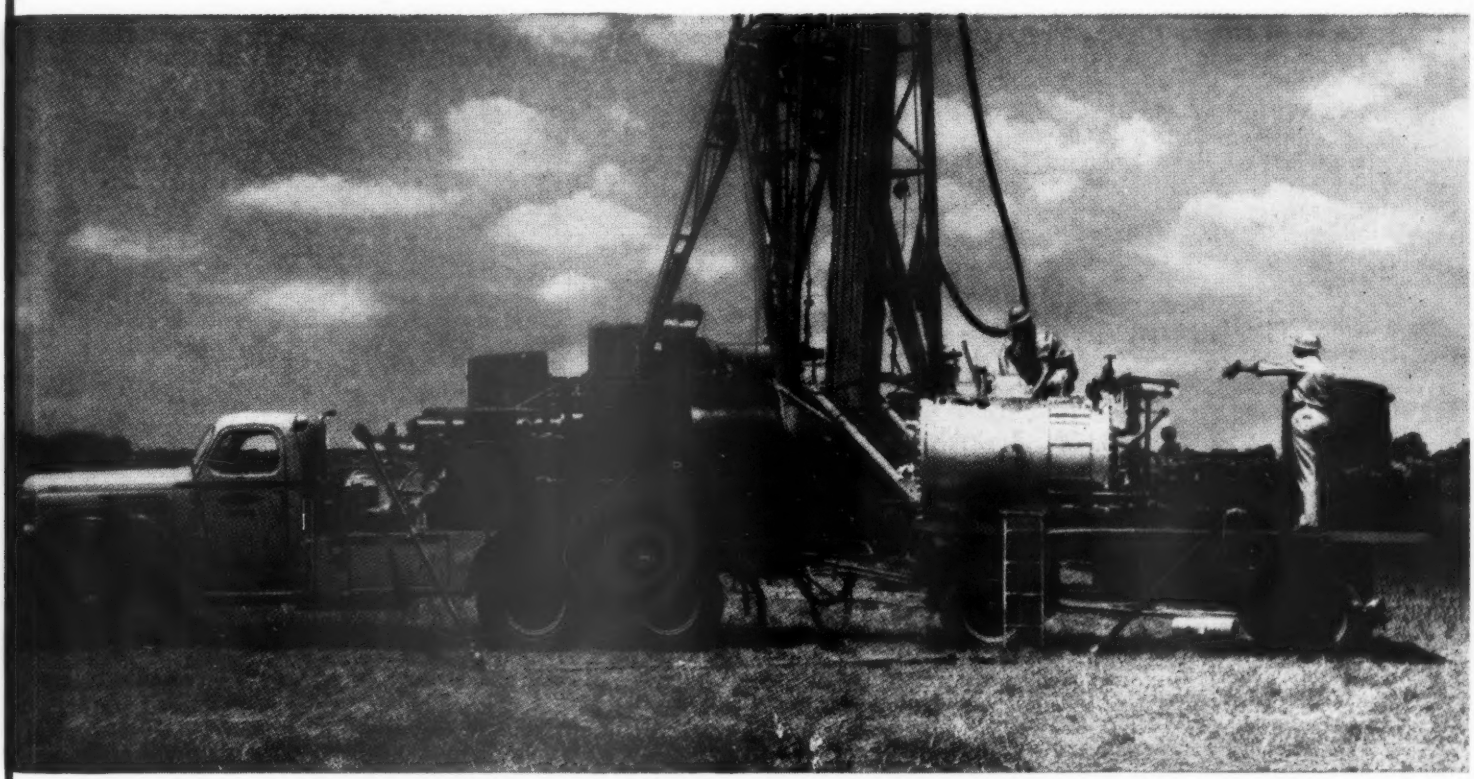

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pipeline developments

● **HUGE GAS LINE EXPANSION.** Facilities to increase capacity of natural gas pipe line systems in the United States by more than 1,250,000,000 cu ft daily were authorized by the Federal Power Commission in the six-months' period between July 1 and December 31, 1947.

Estimated cost of these facilities was $303,218,392, which figure includes purchase cost of the Big and Little Inch war emergency oil pipe lines by Texas Eastern Transmission for natural gas transmission operations.

A total of $277,294,689 of the $303,218,392 was for projects costing $700,000 or more, which were planned to benefit nearly 49 major cities and numerous smaller communities in 15 states in all sections of the country and in the District of Columbia. These projects were intended to add at least 1,262,200,000 cu ft daily to the aggregate capacity of the systems.

● **PRODUCTS LINE IN WORK.** A 182-mile products carrier is being built by Sinclair Refining Company from its Arlington terminal between Dallas and Fort Worth to a point near Pauls Valley, Oklahoma. Pacific Pipeline & Engineers have the contract for the 8-in line, and the project is due for completion by April. At Arlington the line will connect with Sinclair's 10-in. products carrier now being built from Houston by way of Bryan.

At the Oklahoma end, the new carrier will connect at Panova pump station with Sinclair's crude oil multiple-trunk system. An 8-in. line of this system will be converted to products for movement to Kansas City and St. Louis.

● **PROPOSE ADDITIONS TO GAS SYSTEM.** Atlantic Seaboard Corporation and Virginia Gas Transmission Corporation, both members of the Seaboard Division of the Charleston Group of the Columbia Gas System, filed an amended application with the FPC requesting authorization to construct additions to their natural gas systems. Cost of the facilities covered by the amended application has been estimated at $20,649,600.

Construction proposed to be undertaken jointly by the two companies consists of a 268-mile, 26-in. gas transmission line extending from the vicinity of United Gas Pipe Line Company's Cobb compressor station near Glendenin, West Virginia, to Rockville, Maryland, where it would connect with the existing main gas transmission line of Atlantic.

In addition, Atlantic would construct a multiple river crossing consisting of four 16-in. lines crossing the Potomac River, a measuring station on the proposed 26-in. line at the West Virginia-Virginia state line, measuring and regulating equipment. Virginia Gas Transmission proposes construction of two measuring stations.

● **SOUTHERN NATURAL GETS FPC PERMIT.** Southern Natural Gas Company plans to construct and operate facilities to increase the capacity of its main natural gas transmission pipe line to 384,500,000 cu ft a day and to serve several new markets in Mississippi and Alabama. FPC has given authority for the project. Cost has been estimated at $12,296,610.

Facilities authorized include installation of compressor units aggregating 8000 hp, 18½ miles of 20- and 22-in. loops; 15½ miles of 6-⅝ in. loop line and other facilities. Temporary authorization to construct some facilities was granted June 5, 1947.

The 1947-48 construction consists of the addition of compressor units aggregating 9000 hp to existing compressor stations, about 130 miles of 24- and 20-in. loops, a 2000-hp branch line compressor station; 33 miles of 12¾-in. line, etc.; extensions to Lexington, Mississippi, and to White Plains, Alabama.

● **SEEKS TO INCREASE CAPACITY.** Kansas-Nebraska Natural Gas Company, Inc., Phillipsburg, Kansas, has applied to FPC for authorization to construct and operate facilities to increase the capacity of its gas pipe line system. Cost of construction has been estimated at $3,130,865.

The facilities proposed include partial looping of the company's Scott-City-Stockton-Phillipsburg and Otis-Plainville lines in Kansas, and the replacement of an existing line between Holdrege and Elm Creek with larger diameter pipe and construction of 35 miles of new line north of Elm Creek, in the state of Nebraska. The company also proposes to construct lateral lines and town border stations for service to the additional towns in these two states. Installation of one 1000-hp additional compressor unit at the company's Deerfield, Kansas, compressor station also is proposed.

● **TO EXPAND GAS FACILITIES.** The Home Gas Company, The Manufacturers Light and Heat Company, and Cumberland and Allegheny Gas Company have FPC authorization to construct facilities and make changes in their gas systems to improve service to existing markets and to increase the efficiency and flexibility of operation of the systems. Total cost of construction has been estimated at $2,690,164.

Facilities authorized for construction by Home include two regulator stations in Deer Park Town, New York, about 26 miles of 12-in. and about 25 miles of 10-in. transmission line, and a total of 1000 additional hp at its Dundee compressor station.

Authorized for construction in Pennsylvania by Manufacturers Light and Heat were a 1000-hp compressor station and connection with Texas Eastern Transmission Corporation in Chester County, two short 14-in. connections with Texas Eastern, a measuring and regulator station, and an additional 375 hp unit at its Waynesburg compressor station in Greene County.

Cumberland and Allegheny was authorized to construct 7 miles of 6-in. transmission line between Terra Alta, West Virginia, and Oakland, Maryland.

● **BEGINS LAYING MEXICAN LINE.** Construction of a natural gas pipe line between Mexico City and the Poza Rica oil fields on the Gulf coast about 250 miles northeast of Mexico City is under way, a spokesman for the government oil company has stated. Antonit M. Amor, active director of Petroleos Mexicanos, said the first one-mile stretch of pipe has been laid. He predicted the project would be completed before the end of 1948.

The line will supply industrial users in Mexico City with more than 35,000,000 cu ft of gas daily.

● **LAY SECTION OF BRAZIL LINE.** A 50-mile section of the giant pipe line uniting Buenos Aires, Brazil, with southern oil fields at Comodoro Rivadavia has been laid down in 40 days, it was announced last month. The pipe line is designed to supply the industrial area around Buenos Aires with natural gas from the fields of the state-owned oil monopoly. Its total length will be about 960 miles.

● **TRANS-ARABIAN LINE PROGRESSES.** A decision to proceed actively with construction of the 1040-mile Trans-Arabian pipe line was reached at the bi-monthly board meeting of Trans-Arabian Pipe Line Company, it was announced by B. E. Hull, president, in San Francisco.

Hull said that present plans contemplated completion of the line in 1950 as originally scheduled. There has been no stoppage of work on the 840-mile section of the line lying within Saudi Arabia, Hull said. He revealed that delays have been encountered on the westerly end because of the disturbances in Palestine, an outbreak of cholera in Syria, which now seems to have subsided, and reports of smallpox in Lebanon.

● **SEEKS TO PIPE CANADIAN GAS.** A proposal to pipe natural gas from Canada into the Pacific Northwest has been put before the Federal Power Commission in an application filed by Northwest Natural Gas Company. The company seeks authority to build 606 miles of 24-in. line from Kingsgate in British Columbia to serve Portland, Oregon, and Seattle, Spokane, Tacoma and Walla Walla, Washington. Gas delivery contemplated was set at 153,000,000 cu ft daily.

The company reported it is negotiating with gas producers in Alberta, Canada, for supply source. Cost of that portion of the project falling in the United States was placed at $41,900,000.

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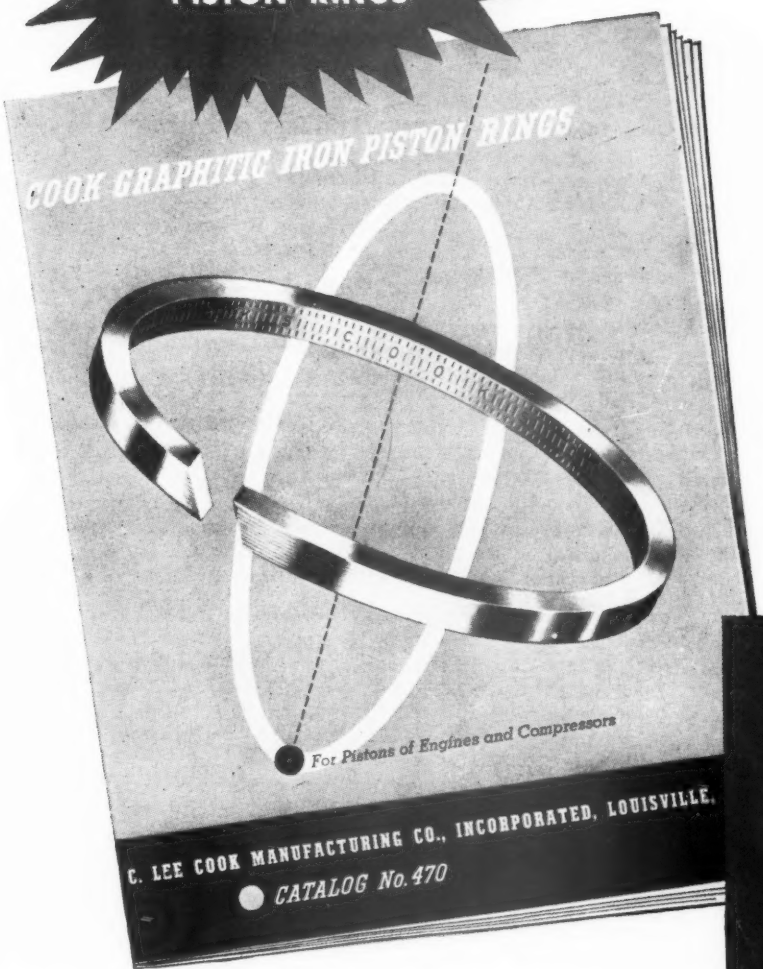
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refining and natural gasoline activities

● **PHILLIPS PLANS GASOLINE PLANT.** Phillips Petroleum Company has announced plans for the construction of a new gasoline plant in Hansford County, Texas, to serve the Detroit, Michigan, area and other locations with natural gas through the Michigan-Wisconsin pipe line.

The new plant will have an initial output of 173,000,000 cu ft of gas a day with an ultimate output of 343,000,000 cu ft. The plant will also produce 54,000 gal of gasoline and 52,000 gal of liquefied petroleum gas. It is expected that 683 gas wells will have to be drilled in the area.

Major items of equipment include a gasoline extraction plant, steam boiler plant, storage facilities, employes' dwellings, field gathering system and booster station. The 24-in gas line to the Michigan-Wisconsin project will be 1,073 miles long and deliveries are expected to start January 1, 1949.

Another expansion move by Phillips is the enlargement of its refining plant at Kansas City, Kansas. The expansion will include a catalytic cracking unit, vacuum unit and catalytic polymerization unit designed to increase production of gasoline, kerosine and other petroleum products.

The additions to the plant, which will be constructed by the C. F. Braun Company of Alhambra, California, are expected to be completed in the fall of 1949.

● **SHELL REFINERY HAS SAFETY RECORD.** In a record-breaking run of 3,476,721 injury-free man-hours, the Shell Oil Company's Wood River, Illinois, refinery has processed more than 16,000,000 bbl of oil, H. D. Dale, refinery manager, announced.

Chief credit for the sustained performance was given to the plant's 20-year-old employee safety program. The 164 days that Wood River's 3,800 employees recently worked without a lost-time injury is a record for all Shell installations. The production figure it helped make possible is a new high for the refinery and is substantially above the plant's rated capacity.

● **BUYS CARBON BLACK UNIT.** A government-owned carbon black plant in Seagraves, Texas, built to produce channel black for the war-time rubber program, has been sold to the Columbian Carbon Company for $1,420,000, WAA announced.

The plant, which has been under lease to the Columbian Carbon Company, is one of the most completely equipped of the carbon black projects fostered by the government. It cost $2,226,179 and has an appraised fair value of $1,779,679.

On a land site of 236 acres are 180 burner houses for carbon black, 17 processing buildings and 19 four-room frame homes. The plant is equipped with channel tables, channel scraper assemblies, carbon collecting hoppers, collecting helicoid screw conveyors, three Mikro pulverizers, a revolving bead machine, motors, tanks, separators, bucket elevators, pumps, etc.

The gas supply line is 12½ miles of 20-in. pipe conveying gas from a treater plant to the carbon black plant. A railroad spur runs three miles from Seagraves to the plant and includes 1000 ft of switch track at the site.

● **HUMBLE TO EXPAND GAS UNIT.** A $2,000,000 addition to the Humble Oil and Refining Company's casinghead gas plant at Kilgore, Texas, is expected to add considerably to the fuel gas supply. The addition will increase by more than 40 per cent the plant's production of propane, a fuel gas used with butane.

● **NEW COMPANY TO PROCESS GAS.** Formulation of Witco Hydrocarbon Corporation for construction and operation of a natural gasoline plant and a carbon black plant, both to cost approximately $3,500,000, in the Barnhart field of Reagan County, West Texas, was announced in New York by Witco Chemical Company.

The two units will process 15,000,000 cu ft of natural gas daily with yield from the gasoline plant placed at 2000 bbl of gasoline, butane, and propane daily. Residue gas will be used in the carbon plant, which will employ the channel process.

Fish Engineering Company, Houston, Texas, has the contract for the gasoline plant. Witco will construct the carbon unit and market its output. Robert I. Wishnick, president of Witco Chemical, heads the new firm.

● **TO BEGIN WORK ON E. ST. LOUIS PLANT.** With completion of preliminary engineering, plans are under way for a replacement and rehabilitation construction program costing several millions dollars at the refinery of the Socony-Vacuum Oil Company, Inc., in East St. Louis, Illinois. It is part of a $45,000,000 expansion and improvement program for the company's refineries.

Charles P. Baker, manager, announced that construction work at the East St. Louis Refinery is scheduled to start late this spring or early in the summer. This will coincide with planned completion of a new crude oil pipe line to the refinery from Texas.

When the replacement and rehabilitation program is completed the refinery's throughput will be increased from 21,000 bbl per day at present to 30,000.

Included in new equipment under the building program are a thermal cracking unit to replace existing thermal units; a naphtha reforming unit, and a distilling unit to furnish crude-oil stock for a war-built catalytic-cracking plant.

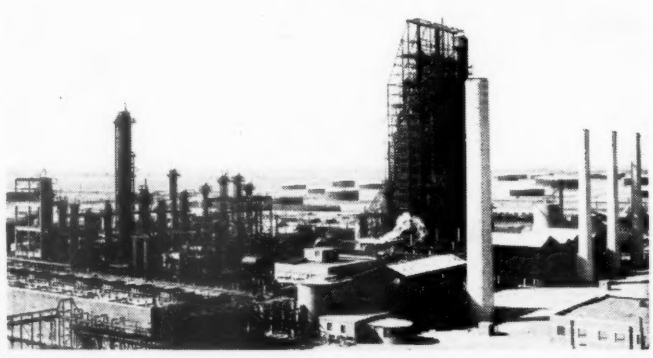
● **CONTINENTAL BUYS 100-OCTANE PLANT.** Purchase by Continental Oil Company of the 100-octane gasoline plant constructed during the war by Defense Plant Corporation was announced by H. G. Osborn, vice president in charge of manufacturing, who said Continental will spend approximately $1,000,000 to modernize the plant. Purchase price for the Ponca City, Oklahoma, plant was $3,125,000.

Modernization of the 100-octane gasoline plant, which Osborn said will be started at an early date, will include conversion of kilns to a solid-bed type, installation of equipment to permit concurrent flow of catalyst and vapors, and major repairs to other equipment.

Continental Oil Company, acting as agent for the Defense Plant Corporation, contracted with the Lummus Company, of New York, for construction of the plant and operated it during the war as lessee. The 100-octane plant includes thermafor catalytic cracking and retreating units with a capacity for cracking 20,000 bbl daily of gas oil and treating 6000 bbl daily; feed preparation and gas concentration units with a capacity of 3000 bbl daily; an alkylation unit with a capacity of 3000 bbl daily, and aluminum chloride isomerization units with a capacity of 1500 bbl daily.

Continental during the war years produced 108,600,996 gal of 100-octane aviation gasoline at the plant and produced an additional 103,370,9898 gal of ingredients for other plants.

Continental Oil Company's 100-octane plant.



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But there were other reasons why the publishers established The Data Book as an annual. Processes change, new ones spring into existence, maps change, new pipelines are constantly being built, new oil and gas fields discovered each year.

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Although data tabulated by years will be repeated, **some 70% of the editorial content of the SECOND EDITION of THE PETROLEUM DATA BOOK will be new.** Already 39 new features have been added to the 1948 Data Book, now in course of preparation. Among these are **a sub-section covering chemicals from petroleum . . . additional maps and analytical charts . . . survey of oil finding costs . . . analysis of oil field discoveries by method of discovery . . . additional data on foreign operations . . . maps of pipe line systems, domestic and foreign . . . key maps and well logs of major oil and gas fields . . . enlarged directory section . . . analysis of drilling operations of major and independent companies . . . survey of lifting costs, etc.**

Obviously, much of the material in the 1947 Edition will be dropped to make room for the new features. However, all data omitted will be included in the Cross-Index of the 1948 edition. Thus Data Book subscribers will build up year by year an invaluable library of petroleum data. Co-incidentally, advertisements will be given a long life of resultful usefulness.

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THE Petroleum Engineer
FEBRUARY, 1948

Deep drilling is finding oil

By ERNESTINE ADAMS,
Associate Editor

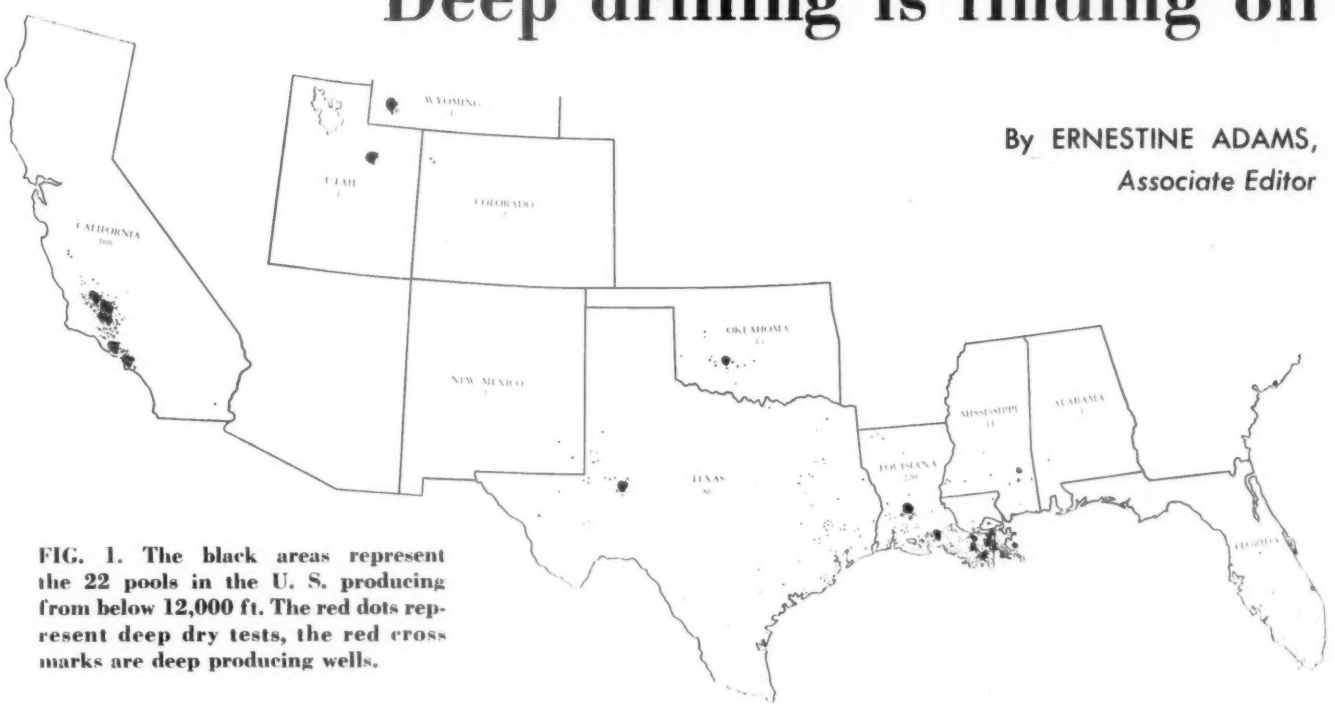

FIG. 1. The black areas represent the 22 pools in the U. S. producing from below 12,000 ft. The red dots represent deep dry tests, the red cross marks are deep producing wells.

OPERATORS in 1947 went on a deep-drilling splurge despite high costs, proving again that the chance of profit offered by high prices for crude oil pushes exploration far, wide, and deep.

EXCLUSIVE

During the year a total of 144 wells were drilled below 12,000 ft, making 461 wells in this classification. All except 12 are in the United States. Table 1 and Fig. 2 show the tremendous increase in deep drilling in the last three years.

Results of the deep-drilling movement have been interesting in all cases, encouraging in a growing number of areas. Operators seem to like the challenge of a giant drilling job and they are learning that one deep well can be as valuable as two or more shallow ones.

● **Economics of deep drilling.** Despite the huge expenditures involved in deep drilling, the balance sheet for the entire program is probably close to paying for itself; at least it will be in the black soon if the picture continues to improve as it did in 1947. Granted that no profits have been made, the oil industry certainly has high expectations of making the investment pay if the upward curve in number of deep tests means anything.

The striking fact concerning deep drilling in 1947 is that out of 144 wildcats, semi-wildcats, and a few development wells the startling number of 35 new fields or new productive sands were discovered, 10 of them below 12.000 ft.

It is hard to classify deep wells. They often have the dual purpose of development drilling in a proved area and exploration in deeper formations. So far as deep formations are concerned, some 90 per cent of all wells drilled below 12,000 ft are wildcats. In the United States there have been since 1938, less than 10 years ago, 22 productive formations discovered below 12,000 ft. This is not such a poor record considering that commercial production of some sort has been obtained from 171 out of 461 deep wells from deep or shallow strata, a proportion of one out of 2.7 wells.

There are many more areas that have shown promise and some tests have yielded small quantities of oil from formations below 12,000 ft but were shut in for some cause or another.

The fortunate, economic balance in deep drilling, however, is due to considerable extent to the development phase of the tests. The shallow well costs much less but examines only one or two sands. The deep well operator, instead of moving the rig, takes his well through a known producing sand and wildcats a lower depth. If he is unsuccessful there he can plug back to upper levels.

The knowledge to be gained from deep drilling is often extremely valuable. In fact, geological information and operational data are products that belong on the black side of the books as much as production of oil and gas.

One of the reasons for the high cost of deep wells is the constant coring and testing. Two tons of samples were taken from the world's deepest well in Oklahoma and that requires one of the most expensive items in a deep drilling operation—time.

Knowledge of equipment and machinery needs for the higher pressures and temperatures, and greater stresses of deep drilling have advanced with drilling practice and the operation of drilling below 12.000 ft grows steadily easier.

● **Costs.** Only a rough estimate can be made of deep drilling costs in the past and, although those from later years are more reliable, they are not exact. The curve for average drilling costs by years, however, presents an interesting picture. In general, it begins at the high and is gradually pulled down by better understanding of problems peculiar to deep drilling and, consequently, by more effective methods of operation aided by improvement and standardization* of

*Progress in deep drilling has been considerably advanced by American Petroleum Institute's Standardization Program.

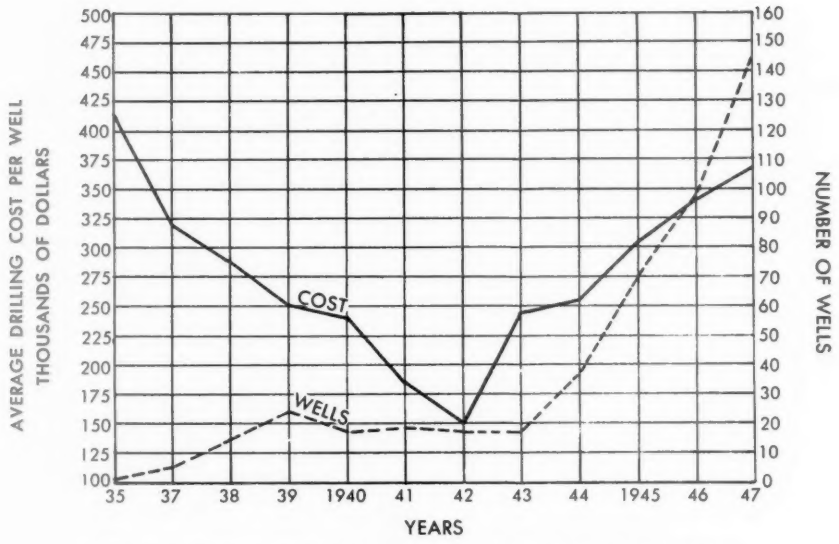

FIG. 2. Average cost of deep wells has risen since 1942. Increase in number of deep tests has accelerated since 1944.

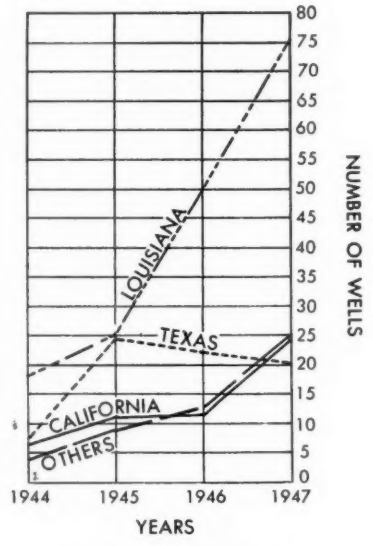

FIG. 3. Location of wells below 12,000 ft.

deep drilling equipment. About the time when the operation became comparatively reasonable in 1942 inflation set in and costs floated upward.

The average cost of drilling a well below 12,000 ft in the United States last year was $363,000, the highest figure since the first test of this depth in 1935 when Gulf Oil Corporation No. 103 J. T. McElroy cost $414,800. This can be attributed mostly to inflation, partly to the greater depths of some of the wells and partly to the increase of wells in high cost drilling areas.

Well depths are increasing as the venturesome drill bites away. For the first time it went below 17,000 ft in 1947. The Superior Oil Company of California's Weller test in Caddo County, Oklahoma, holds the record of 17,823 ft, the deepest well in the world. Standard Oil Company of California was drilling below 17,500 ft at the Maxwell test in Ventura County, California, at the end of the year. In addition, three wells were drilled below 16,000 ft, five below 15,000 ft, and 18 below 14,000 ft.

One of the expensive operations was Magnolia Petroleum Company's 12,874-ft well in the Gulf of Mexico. Several other deep operations are planned for the Gulf tidelands.

No great advance in costs can be laid to deeper drilling, however. A fishing job, for instance, may run up as great expense at a 12,000-ft operation as a 13,000-ft test. In most estimates of drilling costs all this incidental bad luck is included although some companies specified that estimates did not include fishing jobs. Lack of uniformity in keeping records is one reason for the variation in cost of individual wells. From present information it is true there is not much difference in the cost of drilling a well between 12,000 and 13,000 ft and one between 13,000 and 14,000 ft. In the other depth brackets there are hardly enough wells yet to arrive at a reasonable average. It would certainly be useless to figure the cost of drilling below 17,000 ft on the data from two tests.

Actually, location plays a greater part in cost than a thousand or so feet in depth after the 12,000 mark is reached. The least expensive drilling operation in 1947 was a well completed in Iberia Parish, Louisiana, for less than $87,000. Perhaps the most costly was the Superior Weller test, which some oil observers estimated at one and a half million dollars although the company has not revealed the amount. There are several million-dollar wells.

In the three states that had the lion's share of deep drilling the average cost per well in 1947 is estimated at:

Louisiana	$275,000 per well
Texas	378,000 per well
California	392,000 per well

Before 1947 average cost of all wells below 12,000 ft for the three states was:

Louisiana	$230,000 per well
California	333,000 per well
Texas	361,000 per well

All wells outside these three states are much more costly. Formations appear to be harder from the number of bits used and conditions are less well known than in more thickly drilled areas. Heavy rigs doubtless travel farther and time is consumed by cautious drilling even if no fishing or circulation trouble is encountered.

Fig. 3 shows the increase in these more expensive wells, which sends the average deep well cost higher. Proportion of Louisiana wells to the total has not varied much.

Drilling time makes up the greatest share of the costs but materials like drilling mud and chemical additives are growing in importance in deep drilling. One operator noted that almost one-fifth of the cost of a well was spent on these two items.

All in all it appears that the petroleum industry has spent some $150,000,000—a conservative estimate—to explore the depths below 12,000 ft since 1935.

● **Production below 12,000 ft.** During the year 1947 oil was found in 10 new productive formations below 12,000 ft.

TABLE 1.

Years	Number deep wells in world	Estimated average cost per well in U. S. and Canada
1935	1	$415,000
1937	5	320,000
1938	15	288,000
1939	24	251,000
1940	17	242,000
1941	18	185,000
1942	17	150,000
1943	17	244,000
1944	37	253,000
1945	69	303,000
1946	97	340,000
1947	144	363,000

TABLE 2. Deep well operators.

Operator	Number of producing wells	Total deep wells
Amerada Petroleum Corporation	1	2
Atlantic Refining Company		1
Bahamas Oil Company, Ltd.		1
Belridge Oil Company		1
California Company	1	2
*Carter, Amon G.		1
*Coline Oil Company	1	1
Continental Oil Company		2
*Cotton Valley Operators	1	1
*Denver Producing & Refining Co.		2
Four Star Oil Company		1
General Petroleum Corporation	1	2
Gulf Oil Corporation	4	6
*Havenstrite, R. G.		1
Humble Oil & Refining Company	3	19
Hunt Oil Company		2
Lloyd Corporation	2	2
Magnolia Petroleum Company	1	8
McCarthy Oil and Gas	2	2
Mountain Fuel Supply Company	2	2
Pacific Western Oil Corporation	1	2
Pan American Production Co.	1	3
Phillips Petroleum Company		1
Quintana Petroleum Corporation		1
Richfield Oil Corporation		2
Shell Oil Company	12	12
Sinclair Oil Corporation		1
Skelly Oil		1
Slick-Urschel Oil Company	1	1
Standard Oil Company of Ohio	1	1
Standard Oil Co. of California	1	4
Stanclind Oil & Gas Company	2	5
*Stanolind-Westbrook-Thompson		1
Sun Oil Company	1	2
Superior Oil Company	2	6
The Texas Company	8	26
Tide Water Associated Oil Co.	2	2
Union Oil Company of California	3	5
Union Producing Company	1	2
*Union Sulphur Company		1
*Vasen, George		1
Western Gulf Oil Company	1	3
French well		1
Russian well		1
Totals	55	144

*Companies that have not had deep wells prior to 1947.

TABLE 3. DESCRIPTIONS OF WELLS DRILLED BELOW 12,000 FT IN 1947

TD, ft	Complt'd Spudded	Company and well	Field, county or parish, and state	Deepest form. Producing form.	Casing schedule	Initial production, gravity, and choke	Pressure*, gas oil ratio	Remarks
12,000	1-10-47 10-31-46	Magnolia No. B-1 Lahaye Bros.	Mamou, Evangeline, La.	Shale	16″ at 321′, 10¾″ at 4506′	Dry		
12,000		Regie Autonome des Petroles, Puymarin	France					Wildcat
12,001		Sohio No. 1 Farmers Land & Canal Co. Mallet Unit 1	Holmwood, Calcasieu, La.			30 B 3000 MCF 52° 19/64″	‡3600	Prod. from 10,820-40′
12,005	10-24-47 8- 2-47	Humble No. 1 Jennie Kule McKerall	Big Bayou Pigeon area, Iberia, La.	Sandy shale lime	20″ at 114′, 13⅜″ at 2473′, 9⅝″ at 9000′	Dry		Wildcat
12,006	7-13-47 2- 2-47	Stanolind No. 1 Latrielle Estate	South Jennings, Jeff Davis, La.		16″ at 80′, 10¾″ at 3088′, 7″ at 10,233′	Dry		Deepest in area. No salt yet
12,007		McCarthy No. 1 Marie B. Nickell	Brazoria, Texas	Frio		75 B cond. ¼″ 3500 MCF 50.1°	‡2650 50,000	Wildcat. Discovered Scoby Lake field. Perf. at 9100-10′
12,020 PB 8988	11- 8-47 7- 2-47	Texas State- Dog Lake Unit 19-2	Delarge, Terrebonne, La.	Shale and lime Sand	16″ at 103′, 10¾″ at 3011′, 7″ at 9590′	200 B 19/64″	‡2350 3198	Extended field. Prod. 8933-86′
12,022	Jan. '48	Slick-Urschel No. 1 Alford	Upton. Texas	Ellenburger Ellenburger	7″ at 9748′, 5″ at 12,022′	888 B ⅜″	©2400, ‡1850	Drilled to 10,384′ by Plymouth Oil. Opened Slick-Urschel field. Prod. 11,885-TD
12,024	12- 2-47 5-14-47	Magnolia No. 2-C Lutcher	East Mud Lake, Cameron, La.	Shale	16″ at 312′, 10¾″ at 4521′, 7″ at 11,874′	Dry		Perf. 10,996′-11,046′
12,024	11-26-46 10- 5-46	Union of Calif. No. 2 Isadore Delcambre	4-14A-5E, Iberia, La.	Upper Miocene	16″ at 167′, 10¾″ at 2854′			Wildcat. DT (drilling time) 52 days
12,051	12 -7-47	Texas No. 1 J. V.	24-2n-23w, Kern, Calif.			Dry		Wildcat
12,051		Skelly et al No. 1 A. Gest	H. Gosling Sur. A-170, Matagorda, Texas	Schist		Dry		
12,056	9- 9-47 1-30-47	Humble No. 2 Lula Wallis	South Mayes, Chambers, Texas	Hd sandy shale	13⅜″ at 3023′, 9⅝″ at 9960′	Dry		Wildcat. DT-187 da.
12,067	Drilling	Union Sulphur Co. No. 1 Harson Unit A	5-10s-3e Lafayette, La.					Wildcat
12,068		Tide Water No. 38 Burras Levee Dist.	Venice, Plaquemines, La.	Salt B-13 Miocene	20″ at 200′, 13⅜″ at 2490′, 9⅝″ at 9477′, 5½″ at 11,967′	227 B 39.1° 5/32″	‡1700 990	Salt dome. Perf. 9770-804′
12,069	9- 9-47 2-28-47	Texas No. B-10 State— Vermilion Bay	Vermilion Bay, Iberia, La.	Salt Sand	13⅜″ at 2026′, 7″ at 9956′	Gas 12/64″		Perf. 9840-56′. Gas well cleaned and shut in. No gauge
12,070	Fishing	Pacific Western, Unit No. 1	SE NE 24-14s-7e Carbon, Utah			8880 MCF 98.8% CO_2		Wildcat. Prod. from 11,650-12,000′
12,074	5- 1-47 2-20-47	Union of Calif No. 1 Du Pont	Houma, Terrebonne, La.	Mid. Miocene New sd 40′ thick	16″ at 110′, 10¾″ at 2442′, 5½″ at 12,070′	75,000 MCF		Wildcat. Extension. Anticline-faulted. Prod. 11,930-50′
12,081		Superior No. 1 Moodie	Rio Bravo, Kern, Calif.					
12,086	1- 6-47 10-29-46	Texas No. 18 Delta Duck Club	Delta Duck Club, Plaquemines, La.	Hard shale	10¾″ at 2639′	Dry		Wildcat
12,090	6-20-47 2-12-47	Texas No. 58 State— Lake Pelto	Lake Pelto, Terrebonne, La.	Shale Sand	10¾″ at 2551′, 7″ at 10,959′, 5″ at 11,880′	210 B 275 MCF 34.1° 19/64″	‡2000 1307	60 perf. at 11,300-15′ for prod.
12,091	7- 6-47 2-18-47	Gulf No. 17 La Fourche Basis Levee District	Lake Hermitage, Plaquemines, La.	Shale Miocene 100′	20″ at 121′, 13⅜″ at 2519′, 9⅝″ at 9179′ 5½″ at 12,047′	91 B condensate 3245 MCF 48.7° 5/16″	‡3600, ©5718, +11,855 GOR 35700:1	Wildcat. Extension. Flank of shallow salt dome. Shut in. Perf. 11,895-954′ with 384—15/32″
12,091	Drilling 10- 5-47	Western Gulf Paloma Unit 74-1	Paloma, Kern, Calif.		13⅜″ at 1254′, 7″ at 11,892′			Anticline
12,096	7-26-46 4- 1-46	Texas No. 2 State Lease 335	Chandeleur Sound, St. Bernard, La.	Shale & lime, sand	10¾″ at 2988′, 7″ at 9484′	Dry		Wildcat
12,100	12-22-47 5-10-47	Magnolia No. 1 Drummond	Chitwood, Grady, Okla.	Spiers sand	20″ at 62′, 13″ at 2213′, 7″ at 11,599′	468 B 43° 12/32″	‡3000	Perf. 11,964-98′ with 102 shots. Prod. same depth
12,102	9-26-46 6-27-46	Atlantic Refining No. 1 Grand Lake	19-13S-10e St. Mary, La.	Adeline sand	16″ at 229′, 10¾″ at 2524′	Dry		Wildcat
12,131	5- 9-47 11-25-46	Texas No. 103 La Land & Exploration	Leeville, La Fourche, La.	Shale Sand	13⅜″ at 3137′, 7″ at 10,516′, 5″ at 11,800′	227 B 35° ⅛″	‡1780 363	Perf. 140 shots at 10,535-70′ for production
12,153	8-21-47 3-17-47	Richfield No. 1 Mullis	SE SW 21-15s-29e, Chaves, N. Mex.	Granite	13⅜″ at 342′, 8⅝″ at 3303′	Dry		Wildcat
12,159	7- 4-47 12-30-46	Humble No. 1 Anderson Post Hardwood	Hawthorne, Vernon, La.	Hd. shale & lime	20″ at 97′, 13⅜″ at 2533′, 9⅝″ at 9787′	Dry		Wildcat. Anticline structure DT 178 days
12,159	8-12-47 5-19-46	Coline Oil No. 1 Johnson-Cooper	SE NW SE 1-2n-8w, Stephens, Okla.	Pennsylvanian Sand 25′	13⅜″ at 480′, 7″ at 11,390′	54 B 38.7°	§900, ^500	New field. Prod. 9015-40′. Anticline
12,162 PB 9056	10-28-47 8-10-47	Humble No. C-1 Williams, Inc.	Duck Lake area, St. Martin, La.		20″ at 138′, 13⅜″ at 2427′, 9⅝″ at 9500′	Dry		DT 79 days. Anticlinal structure. Deepest core sandy shale 11,556′
12,188		Sun Oil No. 13 Mrs. A. McKinney	Sun Field, Starr, Texas	Frio	13⅜″ at 1019′	Gas	‡1600 ^1500	Perf. 4640-76′. Gas producer
12,190	2-19-47 12-28-46	Union of Calif. No. 1 Jan J. Lafitte	Fresh Water Bayou Vermilion, La.	Shale and sand	16″ at 168′, 10¾ at 2757′	Dry		Wildcat
12,191 PB 7106	10- 8-47 11-25-46	Stanolind No. 1 E. M. Watkins	East Florence, Vermilion, La.		16″ at 201′, 10¾″ at 2871′, 7″ at 10,901′, 5″ liner 10,826-11,991′	114 B 56° 6/32″	‡1000 320	Field discovery well. DT 192 days. Perf. 6-½″ per ft at 7070-73′
12,200	12- 8-47 5-15-47	Texas No. 1 E. B. Schwing	Bayou Choctaw, Iberville, La.	Shale and sand	11¾″ at 2607′, 7⅝″ at 10,230′	Dry		

*Pressure is indicated by ©flowing casing, ‡flowing tubing, §shut in casing, ^shut in tubing, ©initial reservoir, +datum. Last figure without symbol is gas oil ratio in cubic feet per barrel.

TABLE 3. DESCRIPTIONS OF WELLS DRILLED BELOW 12,000 FT IN 1947

TD, ft	Complt'd Spudded	Company and well	Field, county or parish, and state	Deepest form. Producing form.	Casing schedule	Initial production, gravity, and choke	Pressure*, gas oil ratio	Remarks
12,217	4- 5-47 12- 2-46	Texas No. 14 Jefferson Island Salt Mining Co.	Jefferson Island Iberia, La.	Shale	13⅜" at 2489', 8⅝" at 10,250'	Dry		
12,229	9- 4-47 6- 7-47	Union of Calif. No. 1 Billeaud-Planters	Tigre Lagoon Vermilion, La.	Lower Mio. sd & sh Lower Miocene	16" at 171', 10¾" at 2581', 5½" at 12,032'	Gas		Shut in. New sand and extended field. Prod. 11,638-55'. Anticline-faulted.
12,232	6-24-47 7-23-46	General Petroleum No. 18-36 Tupman	Paloma, Kern, Calif.	Paloma zone Paloma sand	13⅜" at 1000', 7" at 11,920'	686 B 471 CF 28°	⊖100, ‡625 687	Perf. 6-½" per ft 11,844-900'. Anticline structure
12,243	10-14-47 8-15-47	California Co. No. 11 E. P. Brady	South Barataria, Jefferson, La.	Shale	16" at 212', 10¾" at 3019'	Dry		DT of 57 days
12,285		Texas No. 1 State-Willow Bayou 790	Johnson's Bayou area, Cameron, La.			96 B		Wildcat. Perf. 8791-802'
12,296	Testing	Continental No. L-2 KCL	San Emidio, Kern, Calif.					Good shows at 12,244-75'
12,297	3-15-47 10-24-46	Western Gulf No. 16-6 LAAC	Paloma, Kern, Calif.	Paloma zone Symons zone	13⅜" at 1265', 7" at 12,047'	61 B 554 CF 54.5°	⊖650, ‡510 9082	Perf. 6-3/16" per ft at 11,295-335'—11,420-60'. Anticline structure. DT 90 days.
12,307	7-19-47 4-28-47	California Co. No. 9 E. P. Brady et al	South Barataria, Jefferson, La.	Miocene Miocene	20" at 217', 13⅜" at 2028', 7" at 12,307', tub. at 11,810'	168 B condensate 5707 MCF 48.8° ¼"	⊖1500, ‡4600 33,976	Field discovery well. Perf. 180 at 11,821-866'
12,331	12-28-46	Gravis et al No. J-2 Natalbany Lbr.	St. Gabriel, Iberville, La.	Shale	2⅜" at 10,735'	265 B 39° ⅛"	‡1900 1426	New sand
12,332	5- -47	Humble No. 1, Iberville Parish School Board	16-11s-12e, Iberville, La.			Dry		
12,346	1-19-47 10-30-46	Phillips No. 1 Vidrine	35-5s-1w, Evangeline, La.	Sandy shale	20" at 178', 13⅜" at 2548', 9⅝" at 7964'	Dry		Wildcat
12,359		Hunt No. 1 Haynesville Mercantile	9-23n-9w, Webster, La.			Dry		
12,364		Superior No. 74-34 Houchin	Paloma, Kern, Calif.	Miocene				
12,366	1-11-47 4-22-46	Gulf No. 16 La Fourche Basin Levee	Lake Hermitage, Plaquemines, La.	Shale Miocene	20" at 109', 13⅜" at 2497', 9⅝" at 9212', 5½" at 12,073'	81 B 3,171,312 CF 45.5° Shut in gas well	‡3750 39,080	New sand. 84 perf. at 12,022-36'. Flank of shallow salt dome. Shut in
12,368	12-31-46 8-23-46	Magnolia No. 1 T. Reed Estate	South Mamou area, Evangeline, La.	Shale	16" at 307', 10¾" at 4520', 7" at 12,365'	Salt water disposal well		Wildcat. 96 perf. at 11,920-32'
12,389	-47 7-15-35	Stand. of Calif. No. 73-30V, Bolsa Chica	Kettleman Hills, King, Calif.	Eocene	6⅝" at 10,921'	600 B 5000 MCF 47.2° ⅜"		New sand. Prod. 12,072-280'
12,409	7- 9-47 10-18-46	Amon G. Carter No. 1 Wight	Sec. 29, Blk. 40, PSL Winkler, Texas	Ellenburger	20" at 223', 13⅜" at 2900', 9⅝" at 5415', 7" at 12,265'	Non-commercial ⅝"		Wildcat. DT 8 mo. 150 bits. Oil from 6300-450'. Also 43° oil from Ellenburger at 12,965-409'
12,415	1-16-47 6-11-46	Shell No. 1 Myles Salt	Weeks Island, Iberia, La.	Miocene Miocene 40'	24" at 106', 16" at 1986', 10¾" at 2947', 7⅝" at 10,401', 5" at 12,413'	446 B 559 MCF 33° 10/64"	‡2550 1223	60 perf. 12,380-95'. Salt dome. DT 198-1½ days
12,440	1947	Bahamas Oil Co test	Andros Is., Bahamas			Dry		
12,454	4-30-47 2-24-47	Humble No. B-1, Verm. Parish School Bd.	Pecan Island, Vermilion, La.	Silty sand	16" at 137', 10¾" at 2726'	Dry		Wildcat. Anticline. DT 63 days
12,476		Shell No. 2 Myles Salt Co.	Weeks Island, Iberia, La.			390 B 34° 10/64"	‡2500, 1231	Prod. from 12,408-23'
12,482	1-11-47 9-15-46	Humble No. 1 A. R. Romaine	Kaplan, Vermilion, La.	Shale Discorbis-Anahuac 21.4'	20" at 82', 13⅜" at 2621', 9⅝" at 9096', 5½" at 11,876'	62 B 11,300 CF 31.2° ¼"	‡40, *5138, +10,800' 183	Wildcat. 84 perf. at 11,060-74'. Salt dome. DT 116 days. Now abandoned
12,489	Drilling	Magnolia No. 1-A Miller	C NW NE 14-16n-9w, Caddo, Okla.					
12,492		Humble No. 1 St. Martin Parish School	Little Bayou Long area, St. Martin, La.			Dry		
12,494	9-19-47 5-22-47	Continental No. 1 W. W. Duson	Jennings area, Acadia, La.	Hackberry	20" at 60', 13⅜" at 1631', 9⅝" at 8449', 7" at 10,665'	Dry		Wildcat. DT 121 days
12,500	1-14-47 10-18-46	Humble No. 1-B Williams, Inc.	Duck Lake area, St. Martin, La.	Sand	20" at 98', 13⅜" at 2710', 9⅝" at 9315'	Dry		Wildcat. Anticline. DT 89 days
12,500	Drilling	Texas No. 1 Dugas & Le Blanc, Ltd.	Napoleonville Dome, Assumption, La.					
12,510		Sun No. 1 Renthrop-Estate	31-15e-14e, Assumption, La.	Upper Miocene		Dry		Abandoned
12,520	8-19-47 5-13-47	Texas No. 59 State-Lake Pelto	Lake Pelto, Terrebonne, La.	Sandy shale, lime Sand	10¾" at 2566', 7" at 12,001'	108 B 688 MCF 37.7° 10/64"	‡1750 6370	88 perf. at 11,188-210' for prod.
12,551		Humble No. B-3, J. M. Burguieres Co., Ltd.	Weeks Island, Iberia, La.			260 B 33.7°	‡1400	Perf. 11,662-705'
12,568	8-14-47 4-30-47	Tide Water No. 36 Buras Levee Dist.	Venice, Plaquemines, La.	Sand B-29 Miocene sand	24" at 103', 20" at 223', 13⅜" at 2490', 9⅝" at 9498', 7" at 12,552'	243 B 32.3° ¾"	‡1450 881	Salt dome structure. Prod. 12,552-68'. DT 94 days
12,610	5- 9-46 2- 9-47	Sinclair No. 1 Lysite Unit,	NE NE NW 35-39n-91w, Freemont, Wyo.	Sandy shale	2" at 62', 13⅜" at 478', 9⅝" at 7172', 7" at 12,578'	Dry		Plugged
12,629	2-28-47 7- 2-46	General Pet. No. 46-1 La Mirada Community	La Mirada, Los Angeles, Calif.	Miocene	13⅜" at 1037', 5½" at 11,900'	Dry		Wildcat. DT 196 days
12,640	1945	Magnolia No. 1-C Lutcher	Jeff Davis, La.					Wildcat

*Pressure is indicated by ⊖flowing casing, ‡flowing tubing, §shut in casing, △shut in tubing, ⊕initial reservoir, +datum. Last figure without symbol is gas oil ratio in cubic feet per barrel.

TABLE 3. DESCRIPTIONS OF WELLS DRILLED BELOW 12,000 FT IN 1947

TD, ft	Complt'd Spudded	Company and well	Field, county or parish, and state	Deepest form. Producing form.	Casing schedule	Initial production, gravity, and choke	Pressure*, gas oil ratio	Remarks
12,648		Pan American No. 1 Louis M. Billeaud	3-11s-5e, Lafayette, La.			Dry		Wildcat
12,650	1947	Lloyd Corp. No. 21	Ventura, Ventura, Calif.	Lower D-7 zone		1000 B 33° $^{16}/_{64}$″	⊖2500, ‡2000	Extended field. 20 perf.
12,678	7- 7-47 2- 9-47	Texas State-Dog Lake Unit 11-1	Dog Lake, Terrebonne, La.	Sandy shale	13⅜″ at 2637′, 8⅝″ at 11,503′	Dry		
12,692	9-19-47 6-23-46	Mountain Fuel Supply No. 2 Unit	Church Buttes, Sweetwater, Wyo.	Morrison Dakota	18⅝″ at 99′, 13⅜″ at 2989′, 7″ at 12,446′, 5½″ at 12,585′	Considerable cond. 14,800 MCF	§5475	Extended field. Anticline. Prod. from 12,433-77′ and 12,512-80′
12,727	2- 6-47 10- 9-46	Humble No. B-12 Petit Anse	Avery Island, Iberia, La.	Sand	16″ at 87′, 10¾″ at 2769′, 9⅝″ at 10,002′	Dry		Wildcat. Anticline. DT 120 days
12,800			Asperon Peninsula, near Baku, Russia					
12,800	6-13-47 2-25-47	Shell No. 4 Hartman Ranch	Ventura, Ventura, Calif.	Lower Pliocene Lower D-7	16″ at 117′, 11¾″ at 3005′, 7″ at 11,985, 5″ at 12,797′	522 B 460 MCF 30.8° $^{13}/_{64}$″	⊖1900, ‡2400 880	Prod. from 12,800′ DT 165 days. Anticline
12,801	5-26-47 10-12-46	Humble No. B-2 J. M. Burguieres	Weeks Island, Iberia, La.	Brittle shale	20″ at 103′, 13¾″ at 2517′, 9⅝″ at 10,495′	Dry		Wildcat. DT 225 days. Anticline
12,849	1947	Quintana No. 1 Alfred Spieckerman	Wm. Newman survey, Gonzales, Texas	Schist	13⅜″ at 1986′, 9⅝″ at 8267′	Dry		Wildcat
12,855	1-11-47 8-15-46	Texas No. 1 Kirby Pet. Co.	Chambers, Texas	Schist	10¾″ at 1516′	Dry		Wildcat
12,868	7-14-47 11-22-46	R. G. Havenstrite No. 15 Lincoln	Del Valle, Los Angeles, Calif.	Mid. Mio. 1200′	13⅜″ at 993′, 7″ at 9800, 5⅝″ at 10,297′, 4½″ at 11,762′	400 B 2000 MCF 43°	⊖1500, ‡1000, ‡3000, ⊕6000, *11,500, 5000	New sand. Prod. from 10,933-11,762′. Faulted anticline. DT 170 days. Perf. 7550-8150′ and 10,100-11,742′
12,874	4- 7-47 8-23-46	Magnolia No. 1 State Lease 673	Gulf of Mexico, off Terrebonne, La.		20″ at 404′, 13⅜″ at 2068′, 9⅝″ at 7222′	Dry		Wildcat
12,894	1947	Union Prod.	Wyo.					
12,924	7- 5-47 12- 3-46	Amerada No. A-2 Jones	Jones Ranch, Gaines, Texas	Granite Devonian	16″ at 320′, 7⅝″ at 11,817′	1053 B 42.4°	⊖100, ‡200, §650, ^400,304	Deep zone wildcat. Anticline. DT 8 mo. Prod. from 11,276-388′
12,940	1947	McCarthy & Gulf No. 1 R. C. Mowery	Pierce Junction, Harris, Texas	Shale and sand		92 B 28.8° $^{11}/_{64}$″	‡210, 350	Perf. at 7564-70′
12,940		Lloyd Corp. No. 18	Ventura, Ventura, Calif.	Lower D-7	5″ at 12,940	1000 B 33° ½″	⊖2500, ‡2000	Extended field
12,946	1947	Pan American No. 1-B Sternenberg Lbr.	Olive, Hardin, Texas			9 B	1975	192 perf. at 9700-806′
12,950	Drilling 6- 7-47	Gulf No. 1 Cleobule Hernandez et al	South Scott, Lafayette, La.	Shale Miocene	20″ at 107′, 13⅜″ at 2517′, 9⅝″ at 9282′, 5½″ at 12,177			Wildcat
12,983	5-29-47 3- 9-47	Texas No. 3 United Lands Co.	Sorrento, Ascension, La.		10¾″ at 3000′	Dry		Wildcat
13,000	7-27-47 4-23-47	Shell No. 1 Weeks Is. State Unit A	Weeks Island, Iberia, La.	Miocene Miocene 40′	16″ at 120′, 10¾″ at 4529′, 5½″ at 12,999′	410 B 560 MCF 33.8° $^{19}/_{64}$″	‡2575 1365	Extended field. 64½″ perf. at 12,911-34′. Salt dome. DT 95 days
13,000		Four Star No. 1 Corcoran-Irrigation	King, Calif.					
13,000	Drilling	Texas No. 12 State-Cote Blanche	Cote Blanche Is. area, St. Mary, La.					Wildcat
13,025	10-13-47 4-30-46	Amerada No. 1-D Jones	Jones Ranch, Gaines, Texas	Granite	13⅜″ at 313′, 8⅝″ at 4323′	Dry		Deep wildcat. Temporarily abd. Dec. '46-Aug. '47. 3 mos. fishing, 4 side-tracking. DT 9½ mos.
13,060		Shell No. 4 Smith-State Unit 1	Weeks Island, Iberia, La.			439 B 34° $^{11}/_{16}$″	‡2500 1040	Prod. from 13,004-020′
13,063	7-22-47 8-21-46	Mtn. Fuel Supply No. 3 Church Buttes Unit	Church Buttes, Uinta, Wyo.	Dakota Dakota	18⅝″ at 100′, 13⅜″ at 2577′, 7″ at 12,945′, 5″ liner at 12,845-13,055′	Considerable cond. 17,406 MCF 48.5°	§5400	Extended field. Deepest test and prod. Rocky Mt. area, 12,933-55 and 12,980-13,050′. Anticline structure
13,072	Drilling	Texas No. 5 City of New Orleans	Leeville, La Fourche, La.					
13,100 PB 12,030	12-23-47 10-26-46	Gulf & Magnolia No. 1 Ida	Chitwood, Grady, Okla.	Lower Penn. Spiers sand	20″ at 50′, 13⅜″ at 649′, 9⅝″ at 6510′, 7″ at 11,660′, 5″ at 13,094′	82 B 445 MCF 44°	‡50 5427	Slight extension. Perf. 11,977-996′
13,122	5-24-47 2- 3-47	Texas No. 2 Kling and Wallet	Fausse Point, Iberia, La.	Shale	13⅜″ at 2508′, 8⅝″ at 10,537′	Dry		
13,129	8-20-47 4-16-47	Stanolind No. 1 State Lease 739	Timbalier Bay, Terrebonne, La.	Shale	20″ at 87′, 13⅜″ at 2304′, 9⅝″ at 8945′	Dry		Wildcat. DT 108 days
13,133	Nov. '47 Sept. '46	Shell No. 1 Walters	14-10n-21w, Beckham, Okla.	Pennsylvanian Granite wash. 100′	13⅜″ at 1117′, 9⅝″ at 5449′, 7″ at 12,212′	469 B 5700 MCF 51.2° ½″		New field. 256 $^{7}/_{16}$″ perf. at 9260-360′. Anticline.
13,251	9- 6-47 11- 7-46	Gulf No. 1 L. L. Majors	Ovett, Jones, Miss.	Anhydrite Glen Rose. Lower Cret. 879′	20″ at 156′, 13⅜″ at 2128′, 9⅝″ at 9004′, 5½″ at 13,157′	187 B Pumping 32.6°		New field. 914 ½″ perf. 12,880-13,082′. 1298 ½″ at 12,911-688′. Faulted dome. Deepest prod. in state. DT 304 days.
13,352	5-10-47 3-15-46	Denver Prod. & Ref. No. 1 Rich	I. & G. N. survey, Grayson, Texas	Shale	15″ at 40′, 10″ at 1190′	Dry		Deepest test in North Texas. Wildcat
13,281	1-13-47 8-29-46	Humble No. 1 Cote Blanche	Cote Blanche, St. Mary, La.	Fine grey sand	20″ at 101′, 13⅜″ at 2601′, 9⅝″ at 8723′	Dry		Wildcat. DT 138 days. Barge rig. Anticline

*Pressure is indicated by ⊖flowing casing, ‡flowing tubing, §shut in casing, ^shut in tubing, ⊕initial reservoir, *datum. Last figure without symbol is gas oil ratio in cubic feet per barrel.

TABLE 3. DESCRIPTIONS OF WELLS DRILLED BELOW 12,000 FT IN 1947

TD, ft	Complt'd Spudded	Company and well	Field, county or parish, and state	Deepest form. Producing form.	Casing schedule	Initial production, gravity, and choke	Pressure*, gas oil ratio	Remarks
13,375	8–10–47 1–21–47	Humble No. 1 Tuscon Corp.	Laxahatchee, Palm Beach, Fla.	Anhydrite & lime	30″ at 41′, 26″ at 177′, 18⅝″ at 871′, 9⅝″ at 5659′	Dry		Wildcat. DT 200 days. Anticline
13,385	11–19–47 6– 8–47	Shell No. A-2 Shell-Lloyd	Ventura, Ventura, Calif.	Lower Pliocene D-7 zone in Lower Pliocene	16″ at 120′, 11¾″ at 3100′, 7″ at 11,740′, 5″ 13,380′	812 B 592 MCF 34.1° 14/64″	⊖1100, ‡1850, 729	Anticline. DT 152 days. Perf. at 12,505-13,380′
13,423	3–25–47 1– 9–47	Humble No. 1 State Lease 732	Hog Bayou Bay, St. Mary, La.	Shale and sand	20″ at 115′, 13⅜″ at 2680′, 9⅝″ at 9500′	Dry		Wildcat. DT 75 days. Anticline
13,564	7–13–47 3–20–47	Texas No. 1 Braddish-Johnson	19-18s-26e, Plaquemines, La.	Shale and sand	11¾″ at 2582′, 7⅝″ at 11,988	Dry		Wildcat
13,570	Drilling	Union Producing No. 3 Buckley-Bourg	Delarge Terrebonne, La.		2⅜″ at 5150′			
13,620	2–27–47 9–29–45	Stanolind No. 1 Eva B. Kayser	Addis Deep, Ector, Texas	Ellenburger Pennsylvanian	13⅜″ at 255′, 9⅝″ at 3943′, 5½″ at 13,620′	160 B 33°	Low GOR	New field. 214 perf. at 8495-565′
13,628		Superior No. 1-A Gulf of Mexico	Lease 884, Blk. 71, 19 mi off Terrebonne, La.			Dry		Wildcat. Deepest test in Gulf
13,728	2–27–47 8–13–46	Texas No. 2 Bender Estate	Humble area, Harris, Texas	Schist	13¾″ at 1455′ 9⅝″ at 8196′	Dry		
13,811	11–18–47 9– 5–46	Magnolia No. 1 Winter	CSW NE, 9-19n-20w, Dewey, Okla.	Wilcox	20″ at 330′, 17¼″ at 3555′, 13⅜″ at 3738′, 7″ at 12,949′	Dry		Wildcat
13,815	1–19–47 5–29–45	Stanolind-Westbrook-Thompson No. 35-A Hendrick	Hendrick, Winkler, Texas	Ellenburger	13⅝″ at 2525′, 9⅝″ at 4850′, 5½″ at 13,808′	Dry		Wildcat. DT 485 days
13,941	11–30–46 7–11–46	Union of Calif. No. C-4 Louisiana Furs	Fresh Water Bayou, Vermilion, La.	Middle Mio 60′	16″ at 168′, 10¾″ at 1000′, 7⅝″ at 11,929′	Shut in gas well		Anticline
14,000	9–24–47 9– 1–46	Shell No. 53-30 KCL-A	Ten Section, Kern, Calif.	Rio Bravo Vedder "53" sand. 60′	14″ at 987′, 9⅝″ at 9528′, 7″ at 12,148′, 5″ at 14,000′	572 B 440 MCF 35.4° 32/64″	⊖1750, ‡350 770	New sand. Domal. 160 ½″ perf.
14,000	Drilling	Texas No. 2 Realty Operators	Vacherie, St. James, La.					
14,000	Jan. '48	Shell No. 1 Smith-State Unit B	Weeks Island, Iberia, La.			476 B 33°		Prod. from 13,846-62′
14,000	Drilling	Texas No. 4 State— Barataria Bay	Queen Bess Island, Jefferson, La.					
14,003	Testing 7– 9–45	Richfield No. 21-33 CLA	North Coles Levee, Kern, Calif.		9⅝″ at 8429′, 7″ at 12,317′	Testing		Wildcat in deep zone. DT 281 days
14,006	1947	Pan American No. 1 C. P. Boudreaux	2-19s-17e, Terrebonne, La.			Plugged		Wildcat
14,104	1947	Beldridge 62-W-33	South Beldridge, Kern, Calif.			Dry		Wildcat
14,035	Shut in 1947	George Vasen No. 1 Tung Oil Corp.	9-2s-11w, Stone, Miss.					Wildcat. Deepening old well. Deepest open hole
14,220		Superior No. 2 State-L. L. & E.	Four Isle dome area, Terrebonne, La.		7″ at 14,024′	180 B 2000 MCF 48.4°	‡4300	Field discovery well. Perf. 12,770-80′ and 13,455-65′
14,238	Testing 10– 7–46	Stanolind No. 1 Briscoe Unit	C NW SW, 4-4n-5w, Grady, Okla.	McLish	13⅜″ at 521′, 9⅝″ at 6960′, 7″ at 13,670′	18 B per hr ½″		Wildcat. Anticline. Deepest production but well not complete. May drill deeper
14,331	6– 1–47 3–19–46	Texas No. 1 W. M. White	Fairfield, Freestone, Texas		10¾″ at 2091′, 7⅝″ at 8395′	8500 MCF		Prod. from 4203′
14,382	10–18–47 11–12–46	Humble No. 1 Jas. C. Baldwin	Tamina area, Montgomery, Texas	Broken sandstone	20″ at 82′, 13⅜″ at 3015′, 9⅝″ at 9485′, 5½″ at 14,382′	Non-commercial		Wildcat. Anticline. DT 338 days
14,397	3–27–47 10–28–46	Shell No. 3 Smith-State Unit 1	Weeks Island, Iberia, La.	Miocene Miocene, 300′	16″ at 105′ 10¾″ at 4521′, 7″ at 13,345′, 5″ at 14,395′	502 B 588 MCF 33° 19/64″	‡2700 1171	Salt dome. DT 138 days. 64 15/32″ perf. at 13,867-888′. Extended field. Second deepest producing well
14,423		Shell No. 5-71	Jumping Pound, Alberta, Canada			10,000 MCF		
14,533	Drilling	Humble No. 1 State-Calcasieu 1256	Calcasieu Lake, Cameron, La.		7″ at 14,018′			Some gas at 13,993-14,002′. Also perforated at 13670-78′
14,629	7–18–47 5–30–46	Humble No. 1 P. H. McKnight	Hawkins area, Wood, Texas	Cotton Valley, salt Rodessa, 30′	20″ at 107′, 13⅜″ at 1626′, 9⅝″ at 5476′ open hole	2.18 B 1100 MCF 57.2°	⊖2278, ‡650, ⊖3495, ⁺8612, 960, 18994	New field. Anticline. DT 24 days may be record. Work done by company Rig No. 32. Prod. 8935-9040′
14,950	3–19–47 10–21–44	Shell No. 48A Alamitos	Long Beach, Los Angeles, Calif.	Schist conglom'rte Lwr. Brown and Upper Deep	18⅝″ at 1002′, 13⅜″ at 3512′, 9⅝″ at 7021′, 6⅝″ 12,851′, 4½″ at 14,947′	78 B Pumping 27°		Wildcat in deep zone. Perf. at 4916-6240′. DT 406 days.
14,967	3–31–47 (deepen) 9– 6–46	Cotton Valley Operator's Comm. No. 2 Sam Banks	Cotton Valley, Webster, La.	Louann salt Davis sand, 10′	13⅜″ at 585′, 9⅝″ at 5718′, 7″ at 10,359	301 B cond. 4300 MCF 65° ¼″	⊖1800, ‡1500, §2200, ^2100, ⊖4600, ⁺8600, 14,600	Anticline. Deepened from 5800′ to TD in 207 days. Penetrated salt from 11,666-14,967′ and never went completely through. May be world's record salt penetration
15,000	Drilling	Texas No. 6 State— Atchafalaya Bay	Belle Isle St. Mary, La.					
15,050	Drilling 12–12–46	Denver Prod. & Ref. No. 1, School Land-A	C SE SW 16-10n-9w, Caddo, Okla.					Wildcat
15,092	9– 2–47 3– 1–47	Western Gulf No. 1 S. P.	Paloma area, Kern, Calif.	Santa Margarita	13⅜″ at 2329′, 9⅝″ at 10,552′, open hole	Dry		Wildcat. Anticline. DT 173 days
15,140	7–10–47 1– 4–47	Humble No. 2 Cote Blanche Fee	Cote Blanche, St. Mary, La.	Sandy shale	20″ at 112′, 13⅜″ at 2694′, 9⅝″ at 10,567′	Dry		Anticline. DT 122 days

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TABLE 3. DESCRIPTIONS OF WELLS DRILLED BELOW 12,000 FT IN 1947

TD. ft	Complt'd Spudded	Company and well	Field, county or parish, and state	Deepest form. Producing form.	Casing schedule	Initial production, gravity, and choke	Pressure*, gas oil ratio	Remarks
15,155	4- 1-47 11- 7-45	Gulf No. 1 State of Florida	2-T67S-R29E, Monroe, Fla.	Limestone	24″ at 173′, 20″ at 602′, 13⅜″ at 2985′, 9⅝″ at 8027′	Dry		Wildcat. DT 511 days. Deepest Florida test
15,523	7-23-47 11-17-46	Texas No. 1 La Fourche Basin Levee District	Queen Bess Is. area, Jefferson, La.	Hd sdy sh lm	13⅜″ at 2981′, 8⅝″ at 12,016′, 5½″ at 13,998′	48 B 6,188,296 CF 44.1° ¼″	‡4200 111,000	Wildcat discovery. 144 perf. ½″ at 13,879-904′. DT 219 days. Deepest prod. in world in 1947. Deepest Louisiana test
15,730	1947	Superior No. 1 Cassie Bradford	1-3n-13w, Forrest, Miss.		7⅝″ at 12,181′, 5½″ at 15,700′			Wildcat. Deepest Mississippi test.
16,006	8- 7-47 5-26-46	Texas No. 6 Yturria Land & Livestock Co.	Raymondville, Willacy, Texas		13⅜″ at 2128′, 7⅝″ at 10,624′	Dry		Deepest Texas test
16,279		Standard of Calif. Coles Levee	Kern, Calif.					
16,668	1947 12-31-45	Pacific Western No. 1 National Royalties	Miramonte, Kern, Calif.			Abandoned		Wildcat. Tools twisted off in bottom of hole
17,696	Drilling 6- 6-47	Standard of Calif. No. 1 Maxwell	Montalvo area, Ventura, Calif.					Perfect drilling job to date. Deepest in California
17,823	8-13-47 4- 4-46	Superior No. 51-11 Weller	NW NW NW 11-8n 12w, Caddo, Okla.	Springer shale	9⅝″ at 10,200′, 7″ at 16,351′	Dry		Wildcat. Deepest hole in world. Completed successful fishing job at 17,236′. Tested from about 9000′ to TD

*Pressure is indicated by °flowing casing, ‡flowing tubing, §shut in casing, ^shut in tubing, ®initial reservoir, •datum. Last figure without symbol is gas oil ratio in cubic feet per barrel.

This does not include at least 10 other tests that found oil and gas in non-commercial quantities at those depths.

Four of these pools are in Louisiana. The Texas Company opened Lake Pelto field in Terrebonne Parish with production from 12,397-415 ft. (See 12,602. Table 3. Other 1947 wells can be found in Table 3 according to their total depth.) Superior discovered Four Isle Dome field, also in Terrebonne, with production from 12,770-13,455 ft and a total depth of 14,220 ft.

Two other productive formations in the state were new deep sands in old pools. Gulf Oil Corporation opened a pool at 12,022-36 ft in Miocene formation after reaching a total depth of 12,-366 ft in the Lake Hermitage pool, Plaquemines Parish. Production is mostly gas and it has been shut in for the present. The Texas Company went to 15,523 ft in the Queen Bess Island field, Jefferson Parish, and found production at 13,879-904 ft, proving a new sand.

Each of the states, California, Mississippi, Oklahoma, Texas, and Utah, has a new deep producing formation, although all the discovery wells have not been completed. California also has a strong possibility of a second deep field. They are all highly interesting and important to the deep drilling movement.

Stanolind Oil and Gas Company's Briscoe Unit in Grady County, Oklahoma, is expected to be completed for the world's deepest producer. That title is held now by Texas Company's well, Queen Bess Island, Jefferson Parish, which produces from 13,879,904 ft with a total depth of 15,523 ft.

At the Briscoe a drillstem test at 13-634-875 ft produced 463 bbl of oil in 24 hr. A late drillstem test in the McLish sand, topped at 14,165 ft, brought a flow of 18 bbl of oil an hr. Total depth of the extraordinary well is now 14,238 ft and deeper drilling is contemplated.

The Chitwood field in Grady County lacks only a couple of feet of reaching 12,000-ft producing depth in the Pennsylvania sand.

An old well that has been brought to life is Standard of California Bolsa Chica 73-30, Kettleman Hills, Kings County, California. Spudded in on July 15, 1935, the well was reworked and drilled deeper during the last two years. It was completed around the first of the year for the substantial daily production of 600 bbl of 47.2 gravity oil and 5,000,000 cu ft of gas from 12,072-280 ft.

Continental No. L-2 Kern County Land Company (TD 12,296 ft) is said to have had good shows in cores taken from 12,-244-75 ft. This area of San Emidio has held considerable deep exploration interest and another deep pool in Kern County is expected.

Texas was introduced to below 12,000-ft production with an ugly duckling well that turned into a beautiful prospect. The Plymouth Oil Company drilled to 10,384 ft in Upton County near the Reagan County line in 1941. It was strictly a wildcat operation, nine miles north of Big Lake field. In 1947 Slick-Urschel Oil Company obtained a farm-out in the well and drilled it to 12,022 ft. And a swan it was. It is producing at intervals from 11,885 ft to the total depth. The Ellenburger lime was topped at 11,020 ft and has not been entirely penetrated. The whole 1000 ft had showings.

Mississippi also has its first production below 12,000 ft. Gulf No. 1 L. L. Major, a wildcat in Jones County, opened up the Ovett field with production at intervals from 12,011 ft to 13,082 ft in the Glen Rose sand. Total depth is 13,-251 ft. The well was pumping 184 bbl a day of 32.6 gravity oil.

Utah provided the most unusual deep well of the year, known as the "Ice Cream Well." The well produced an estimated 8,880,000 cu ft of gas a day of which nearly 99 per cent was carbon dioxide. Pacific Western Oil Corporation, the operator, took the test to 12,070 ft on the Gordon Creek Structure in Carbon County. It is now fishing and plans to drill deeper. The first well to go below 12,000 ft in the state, the gas was from 11,650 to 12,060 ft. The well may yet be completed as a CO_2 producer. One million cubic feet of CO_2 makes about 50 tons of dry ice, which sells for $20 to $25 a ton.

In previous years Louisiana has discovered seven producing strata below 12,000 ft. The first one was opened by Buckley-Bourg No. 1, operated by Fohs Oil Company. In DeLarge field, Terrebonne, it came in June 26, 1938, not long after the famous Continental Kern County well in California, and actually produced from greater depths, 13,266 ft, but production was mostly gas. Several wells were drilled to the productive formation, however, and in 1943 Union Producing Company found a deeper oil sand in the same pool at 13,475-90 ft after drilling to 13,560 ft.*

Weeks Island field, in Iberia Parish, was discovered by Shell Oil Company in 1945 and appears to be one of the most productive. There are already at least nine wells on the salt dome, seven being drilled by Shell in 1947. Humble Oil and Refining Company has one.

A new sand in Lapeyrouse field, in Terrebonne, was discovered by the British American Oil Producing Company in 1946 with the A. M. Dupont Corporation well, which was drilled to 13,857 ft. Production was found at 12,632-40 ft.

Humble opened South Oberlin field, Allen Parish, in 1946. The total depth of No. 1-B Mrs. J. A. Bel Estate is 13,-150 ft and production comes from the Wilcox sand at 12,658-62 ft.

Lesser productive areas that are promising but have not proved of much commercial value are a new deep sand in Venice field, Plaquemines, found by Tide Water Associated in 1946 and Lirette field, Terrebonne, discovered in 1942.

Wasco field in Kern County, California, is the first deep field on record. Opened by Continental KCL A-2 in April, 1938, there were 10 producers in the field, which have yielded close to 5,000,000 bbl of oil in the years since. KCL A-2, which held the world depth record of 15,004 ft for six years, was finally abandoned in 1947.

*See "Deep Exploratory Wells on Increase," *The Petroleum Engineer*, February, 1947, for descriptions of wells prior to 1947.

The Shafter field, also in Kern County, was discovered by Continental KCL C-2 in 1941 (TD 12,934 ft). Three other producing strata were tapped in 1946. Chanslor-Canfield Midway No. C-11 Hobson, total depth 14,155 ft, discovered Rincon field, Ventura County, with production at 13,560 ft. A new sand in the Ventura Avenue field, called Lower D-7 zone, was penetrated by Lloyd Corporation No. 18 with total depth of 12,940 ft. General Petroleum Corporation No. 1 Librown found production in a stratigraphic trap at 12,037-527 ft, LaMirada field, Los Angeles County. Total depth is 12,600 ft.

Wyoming became the third state with 12,000-ft production in 1946 when Mountain Fuel Supply Company Unit No. 1 opened a gas field in the Dakota formation at 12,550-697 ft after reaching a total depth of 12,895 ft. This is the Church Buttes field, Uinta County, where Mountain Fuel in 1947 extended the proved area with two more successful deep wells producing from the same formation.

● **Operators.** With the exceedingly high cost of deep wells, it would not be surprising if only a few of the largest and wealthiest companies ran the risks of deep drilling but that is far from fact. It does require more money and more nerve but neither has to date been lacking. Seventy-four companies have taken a chance on one or more deep tests.

Of the 461 wells that have gone deeper than 12,000 ft, The Texas Company leads with at least 56 wells and Humble Oil and Refining is second with 52 wells or more. In third place, Shell Oil has at least 28 wells. This company has 12 producers from 12 deep wells, most of them development wells. The list of operators is found in Table 2 in this article and in the February, 1947, article.

● **Bits.** A gauge of information density in various localities is evident from the number of bits used. In Louisiana, where deep formations are not so hard, the average number of bits used per deep well is 71, individual wells using as few as 20 bits. Formations in Texas are almost twice as hard to penetrate and wells average 130 bits to get below 12,000 ft. California areas require considerably more than Texas, reaching an average of 183 bits per well.

Other areas have not had enough deep drilling to reveal much by average bits used. Last year the 13,747-ft well drilled by Imperial Oil and Shell Oil in Alberta, Canada, blunted 601 bits.

Costs naturally increase with these hard formations. The Canadian well cost approximately $1,000,000. Original exploration costs are, however, included in this amount.

● **Drilling time.** Another item of interest is the fact that drilling time seems to be on a downward trend although it is difficult to get an accurate picture. Drilling time in some deep wells, like the Standard well in Kettleman Hills, begun in 1935, has no relation to the interval between spudding and completion.

There are a large number of wells drilled below 12,000 ft in two or three months, however, and a future chart will doubtless show a steep decline in average drilling time, which should tend toward lowered costs.

Humble's wildcat in Wood County, Texas, appears to have the record so far on rapid drilling. Drilling time was 24 days to a total depth of 14,629. Work was done by the company's rig No. 32.

● **Distribution.** Louisiana again led the states in the number of 12,000-ft wells. The 76 for 1947 brought the state's total to 144 deep wells (Table 4). California is second with 24 wells, which makes 108 below 12,000 ft on the West Coast. Texas now has a total of 86 with the 20 added this year.

Oklahoma had the largest increase in deep drilling, the 9 new wells giving the state 14 deep ones including the record depth holder. Utah was the only new state added to the list of those having deep tests, making 11 in all.

There have been rumors of several wells in Russia below 12,000 ft and one has been allowed although no authentic information has been received. Two tests in France are said to have reached such depths and contradictory reports do not clarify the information. So again one was included. If any were drilled in South America to 12,000 ft the data have not arrived in time for this survey. It is known some deep tests are scheduled.

One thing about totals should be explained. The nine wells that were drilling at the end of last year below 12,000 ft but were not completed have been taken from the 1946 wells and added to the 1947 list. Wells still drilling are included if they have passed the depth limit for the list even if not completed.

● **Acknowledgment.** Every company that sent in information about its deep wells has contributed to this survey and without this cooperation the collection would be impossible. After this effort by the companies it is to be hoped that accounts of former operations will aid in deep well drilling of the future. ★ ★ ★

TABLE 4. Deep wells by location.

State and county or parish	Prior to 1947	1947	County total	State total
Alabama	1	0	0	1
Clark	1	0	1	
California	84	24	0	108
Fresno	3	0	3	
Imperial	1	0	1	
Kern	55	12	67	
Kings	3	2	5	
Los Angeles	6	3	9	
Orange	2	0	2	
Tulare	2	0	2	
Ventura	9	7	16	
Colorado	2	0	0	2
Rio Blanco	2	0	2	
Florida	6	2	0	8
Charlotte	1	0	1	
Collier	1	0	1	
Highlands	1	0	1	
Monroe	2	1	3	
Palm Beach	0	1	1	
Louisiana	144	76	0	220
Acadia	3	1	4	
Allen	1	0	1	
Ascension	1	0	1	
Assumption	3	1	4	
Beauregard	4	0	4	
Bossier	1	0	1	
Calcasieu	2	1	3	
Cameron	6	3	9	
Claiborne	1	0	1	
Evangeline	10	3	13	
Iberia	12	13	25	
Iberville	1	2	3	
Jackson	1	0	1	
Jeff Davis	4	2	6	
Jefferson	8	4	12	
Lafayette	0	3	3	
La Fourche	11	2	13	
Plaquemines	11	6	17	
Rapides	1	0	1	
St. Bernard	1	1	2	
St. Charles	3	0	3	
St. James	3	0	3	
St. John the Baptist	1	0	1	
St. Landry	1	0	1	
St. Martin	5	3	8	
St. Mary	17	6	23	
*Terrebonne	22	13	35	
Vermilion	13	7	20	
Vernon	0	1	1	
Washington	1	0	1	
Webster	0	2	2	
Mississippi	8	3	11	
Adams	3	0	3	
Forrest	1	1	2	
Green	1	0	1	
Jeff Davis	1	0	1	
Jones	0	1	1	
Lincoln	1	0	1	
Rankin	1	0	1	
Stone	0	1	1	
New Mexico	1	1	0	2
Lea	1	0	1	
Chaves	0	1	1	

*One is off shore in the Gulf of Mexico.

State and county or parish	Prior to 1947	1947	County total	State total
Oklahoma	5	9		14
Beckham	0	1	1	
Caddo	1	3	4	
Dewey	1	1	2	
Grady	1	3	4	
McClain	1	0	1	
Stephens	0	1	1	
Washita	1	0	1	
Texas	66	20	86	
Anderson	2	0	2	
Andrews	2	0	2	
Brazoria	11	1	12	
Brazos	1	0	1	
Brooks	1	0	1	
Cameron	1	0	1	
Chambers	1	2	3	
Colorado	1	0	1	
Crane and Upton	1	0	1	
Duval	1	0	1	
Ector	2	1	3	
Freestone	1	1	2	
Gaines	1	2	3	
Galveston	1	0	1	
Goliad	1	0	1	
Gonzales	0	1	1	
Grayson	0	1	1	
Hardin	2	1	3	
Harris	3	2	5	
Jackson	1	0	1	
Jefferson	1	0	1	
Kenedy	1	0	1	
Liberty	3	0	3	
Madison	1	0	1	
Matagorda	2	1	3	
McMullen	1	0	1	
Midland	1	0	1	
Montgomery	7	1	8	
Newton	1	0	1	
Nueces	1	0	1	
Pecos	3	0	1	
Reeves	1	0	1	
Shelby	1	0	1	
Smith	2	0	1	
Starr	0	1	1	
Titus	1	0	1	
Trinity	1	0	1	
Upton	0	1	1	
Willacy	2	1	3	
Winkler	1	2	3	
Wood	0	1	1	
Wyoming	1	4		5
Freemont	0	1	1	
Sweetwater	0	1	1	
Uinta	1	2	3	
Utah	0	1		1
Carbon	0	1	1	
The Bahamas		1		1
Canada				5
Alberta	3	1	4	
New Brunswick	1	0	1	
Ecuador				1
France	0	1		1
Germany	1	0		1
Russia	0	1		1
Venezuela	2	0		2
World total	317	144		461

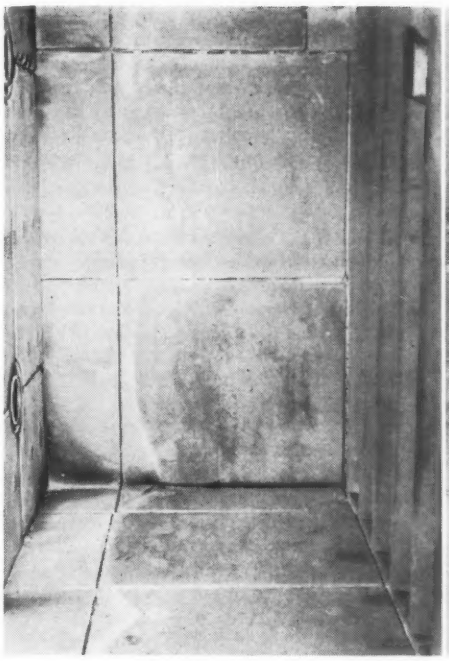


FIG. 1.

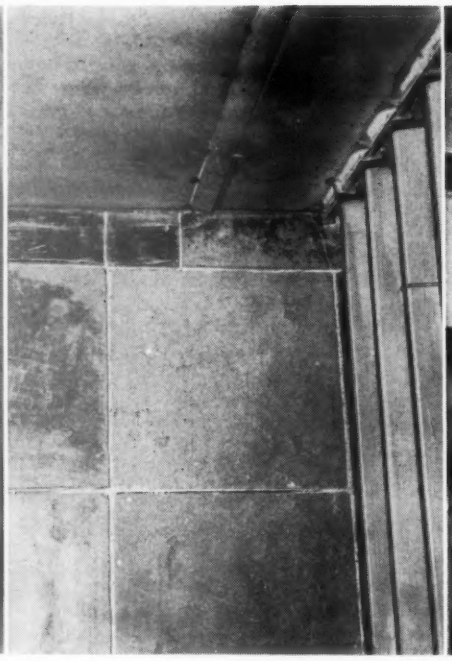


FIG. 2.

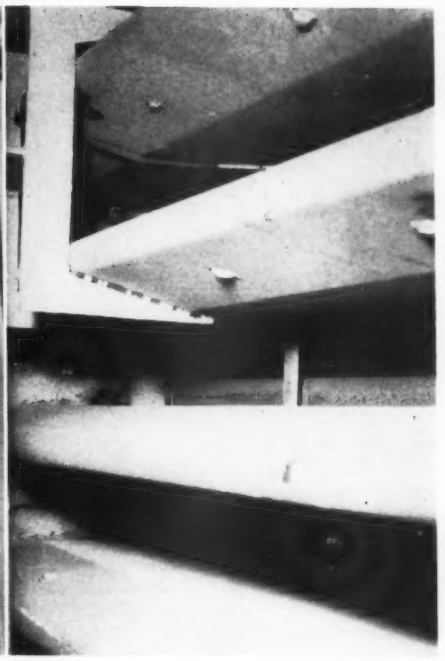


FIG. 3.

First turnaround of Leonard TCC unit

JOHN S. PFARR, Technical Director, Leonard Refineries, Inc.

THE first turnaround of the Leonard TCC unit has recently been completed with an expenditure of only 4557 manhours. After an initial run of 222 days, during which time the unit had an on-stream efficiency of 96.4 per cent, a complete inspection of the plant was begun on October 27, 1947. Using only 40 men per day, two crews of 20 men each, the work of the turnaround was completed in 10½ days. Of the 40 men used, 29 were from the refinery maintenance force and 11 from the operating personnel of the unit. Operation of the plant was resumed on November 6, 1947.

● **On-stream efficiency during initial run.** During the initial run several interruptions of short duration in the operation of the plant occurred. A complete itemization of all off-stream periods and causes thereof is presented in Table 1. It can be seen that the reasons for the off-stream periods were of a minor nature and that out of a total elapsed time of almost eight months, only 116 hours of off-stream time were attributable to the catalytic section of the plant. As stated above, the overall on-stream efficiency of the plant for the initial run was 96.4 per cent.

● **Turnaround summary.** In order to prepare the TCC plant for operation throughout the winter months, the general turnaround was originally scheduled for the end of September. The heavy demand for refinery products, however, necessitated that the operation of the unit be continued for an additional month. In order to expedite the work of the turnaround, a well-defined program of inspection was arranged prior to the shutdown. Through conferences held at the refinery, Houdry and Leonard representatives scheduled the shutdown procedure and the sequence of activities of the various mechanical crafts.

Since March, 1947, when the unit was put into initial operation, the charge to the plant has consisted principally of Reed City and Adams reduced crudes, which have sulphur contents of the order of 0.9 wt per cent. After being preheated to about 840 F in vaporizing heaters, the reduced crude charge is flashed in a tar separator to produce a tar separator overhead vaporized charge for the catalytic reactor and a heavy bottoms product that is subsequently processed into asphalt and heavy fuel oil components. Overhead and bottoms products from the tar separator flash have average sulphur contents of 0.6 wt per cent and 1.1 wt per cent, respectively. Thus the sulphur content of the reduced crude charge and fractions thereof have been sufficiently high that some corrosion of the processing equipment was anticipated from this source. The results of the recently completed inspection, however, are particularly gratifying in that, as discussed below, a minimum use of alloy steel for production against corrosion is indicated to insure the continued satisfactory performance of the plant.

TABLE 1. On-stream efficiency summary.

Cause of off-stream time	Hours	Per cent
Stabilizer clean-up	48.0	25.1
Blower maintenance	41.3	21.6
Circulating water pump failure	63.7	33.4
Power failures	26.7	14.0
Clay hold-up in reactor seal leg	11.3	5.9
Total	191.0	100.0
Total hours on stream— 3-18-47 to 10-27-47	5140.2	
Total hours elapsed— 3-18-47 to 10-27-47	5331.2	
On-stream efficiency		96.4

The turnaround comprised a complete inspection of all items of equipment in the TCC plant—from the charge pump to the final stabilizer in the gas plant section. Pertinent data concerning the manhour requirements for the shutdown work are presented in Tables 2, 3, 4, and 5. Of particular interest is the

FIG. 4.

fact that out of a total of 4557 manhours, 2954 manhours were spent in the inspection and maintenance of conventional refinery equipment such as valves, pumps, gas compressors, heat exchangers, and fractionating towers and only 425 manhours were required for inspection and repair work on equipment in the catalytic section. Furthermore, because of the excellent mechanical condition of the unit, the major portion of the work was accomplished with unskilled labor as illustrated in Table 3. The distribution of manhours expended on the catalytic section according to items of equipment and also according to mechanical craft, is shown in Tables 4 and 5, respectively.

Actually, two of the items of work performed during the shutdown do not come under the category of inspection and repair because they involved changes in equipment design for new processing schemes to be employed in the plant. These were piping changes in the steam superheater section of the vaporizing heaters and the installation of liquid feed apparatus in the TCC reactor. With recent reduced crude charge rates to the vaporizing heaters nearly twice that for which the equipment was originally designed, it was found that there was an excess of steam superheating capacity in the heaters. Therefore, during the shutdown, half of the steam superheating coils were connected in series with the convection section reduced crude coils in order to increase the heat input to the charge and at the same time reduce the steam superheating surface to the desired amount. The liquid feed apparatus, which required slight modification of the reactor internals, was installed to permit the future processing of non-vaporizable stocks in the TCC unit. For example, in the near future it will be possible to charge to the TCC reactor the overhead product from the vacuum flashing of the tar separator bot-

FIG. 5.

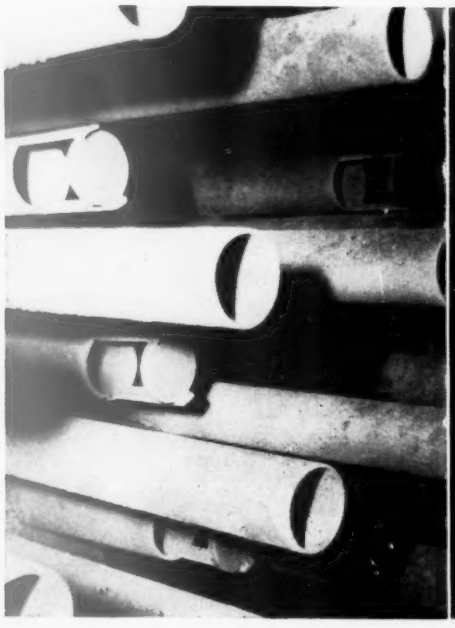


FIG. 6.

TABLE 2. Manhour requirement for total plant by job item.

Job item	Manhours	Per cent
Turnaround		
Inspection and adjustments to catalyst elevator	75	1.7
Miscellaneous work on kiln and reactor	350	7.7
Sand blasting gas and water separator	285	6.3
Painting inside gas and water separator	48	1.1
Replacement of tar separator bottoms lines	501	11.1
Replacement of heater transfer lines	344	7.5
Miscellaneous work on valves, pumps, instruments, electrical equipment, gas compressors, heat exchangers, coolers, fractionating towers, etc.	2954	64.6
Sub total	4557	100.0
New installation and revisions		
Liquid feed installation	275	
Steam superheater piping changes	221	
Total	5053	

TABLE 3. Manhour requirement for total plant by craft.

Craft	Manhours	Per cent
Turnaround		
Welders	200	4.4
Machinists	912	19.9
Instrumentation and electrical	216	4.8
General labor	3229	70.9
Sub total	4557	100.0
New installation and revision		
Welders	302	
Machinists	40	
Instrumentation and electrical	4	
General labor	150	
Total	5053	

TABLE 4. Manhour requirement for catalytic section by job item.

Job item	Manhours	Per cent
Turnaround		
Unheading and heading vessels, etc.	144	33.9
Elevator inspection and adjustment	75	17.6
Reactor clean up	72	16.9
Repairing flue gas compressor	30	7.1
Instrument and electrical maintenance	24	5.6
Circulating water pump inspection and repair	18	4.2
Kiln insulation	16	3.8
Steam drum clean up	12	2.8
Kiln clean up	10	2.4
Make up water pump repair	8	1.9
Miscellaneous	16	3.8
Sub total	425	100.0
Liquid feed installation	275	
Total	700	

TABLE 5. Manhour requirement for catalytic section by craft.

Craft	Manhours	Per cent
Turnaround		
Welders	38	9.0
Machinists	85	20.0
Instrumentation and electrical	24	5.6
General labor	278	65.4
Sub total	425	100.0
Liquid feed installation		
Welders	180	
Machinists	36	
General labor	59	
Total	700	

toms stream. The manhours required for these two design changes amounted to 496. Therefore, the grand total manhours expended during the turnaround was 5053, 4557 for inspection and repairs and 496 for design changes.

The low manhour requirement for the turnaround is in itself evidence of the sound design and construction of this type of TCC installation. It is also well illustrated by photographs of the equipment taken during the shutdown and included herein.

● **TCC kiln.** Figs. 1, 2, and 3 are typical illustrations of the excellent internal condition of the regeneration kiln. Fig. 1 is a view of the internal wall insulation and flue gas collector channels in the top zone of the kiln. The kiln entrance ends of two of the 16 spent catalyst feed pipes are also shown in this photograph. A portion of the internal wall insulation and flue gas collector channel assembly in the bottom zone of the kiln is shown in Fig. 2. Fig. 3 is a view of the air inlet distributor channel assembly and water-cooling coils of an intermediate zone of the kiln. A few panels of wall insulation in the kiln showed a slight amount of erosion. These were repaired with the field application of Panelclad, a new plastic insulation. No mechanical repairs were required on any of the air inlet distributing channels, flue gas collecting channels, or water-cooling coils of the kiln.

All catalytic lines to and from the kiln were thoroughly inspected for possible loss of metal due to erosion and found to be in perfect condition. Likewise, all air and flue gas lines to and from the kiln were inspected to determine the condition of the internal insulation. Again no repair was required for the insulation was found intact throughout. The condition of these lines is typified by Fig. 4, which shows a section of the air inlet manifold to the kiln.

● **TCC reactor.** The TCC reactor was also thoroughly inspected for mechanical defects. Measurements indicated no loss of metal from the reactor shell or internal metal elements from either erosion or corrosion despite the fact that a charging stock of a relatively high sulphur content had been processed. This was particularly encouraging because all parts of the reactor are fabricated of carbon steel. Fig. 5, which shows a portion of the vapor and catalyst tubes of the disengager in the bottom of the reactor, is typical. As mentioned before, the most extensive work in the reactor was the installation of liquid feed apparatus. On the reactor wall above the catalyst bed a deposit of coke was found, which was removed without difficulty.

● **Catalyst elevator.** The new split bucket-type elevator fulfilled all expectations by functioning entirely satisfactorily throughout the 222-day run. None of the off-stream time during the run was due to failure of the elevator mechanism. Moreover, the routine inspection and adjustment of the elevator during the turnaround required the expenditure of only 75 manhours. Fig. 6 is a view of the elevator chain assembly passing over the head shaft at the top of the structure. The bucket partitions, chain links, and traction rim may be seen. The baffles in the foreground of the view are the means by which the regenerated and spent catalyst contents of each bucket are diverted to the kiln and reactor hoppers respectively.

Measurements of the loss of metal from the traction rims on the head shaft as well as from the elements of the chain links indicated that the elevator would operate for a considerable time before a major overhauling was required. For example, the total elongation of the chain during the eight months of operation was only 4 in., equivalent to wear on each of the pin and bushing assemblies of a few hundredths of an inch. The chain knuckles, which contact the traction rims and are subject to more severe initial wear, showed an average loss of metal of about 0.06 in. and the traction rims themselves had lost only 0.017 in. of thickness. Following the inspection, a few adjustments were made to the head shaft after which the elevator was closed up and returned to service.

● **Auxiliary equipment.** The three largest items of repair during the turnaround were the renewal of sections of the transfer lines between the heaters and tar separator, the renewal of the hot tar lines from the bottom of the tar separator, and the cleaning and adjusting of the wet gas compressors in the gas plant.

In the original design study of this TCC installation, it was recognized that the sulphur content of the charging stocks that would be processed might be high enough to necessitate the use of alloy steel construction in many parts of the system. A decision was reached at that time, however, to use carbon steel in several places and determine by experience those critical points where the use of alloy steel was necessary. As previously mentioned, the results of this inspection were gratifying in that severe corrosion was found to have occurred in only the heater transfer lines and tar separator bottoms lines. During the turnaround, these lines were replaced with four 6 per cent chrome alloy steel pipe. In this connection, there was an interesting observation that these lines operated within the critical temperature range for corrosion by the plant charging stocks. For example, the return line from the tar quench cooler to the tar separator showed no corrosion whereas the other tar lines, which operate above 600 F, where severely corroded. Fig. 7 shows the Houdry metal inspector cali-

FIG. 7.

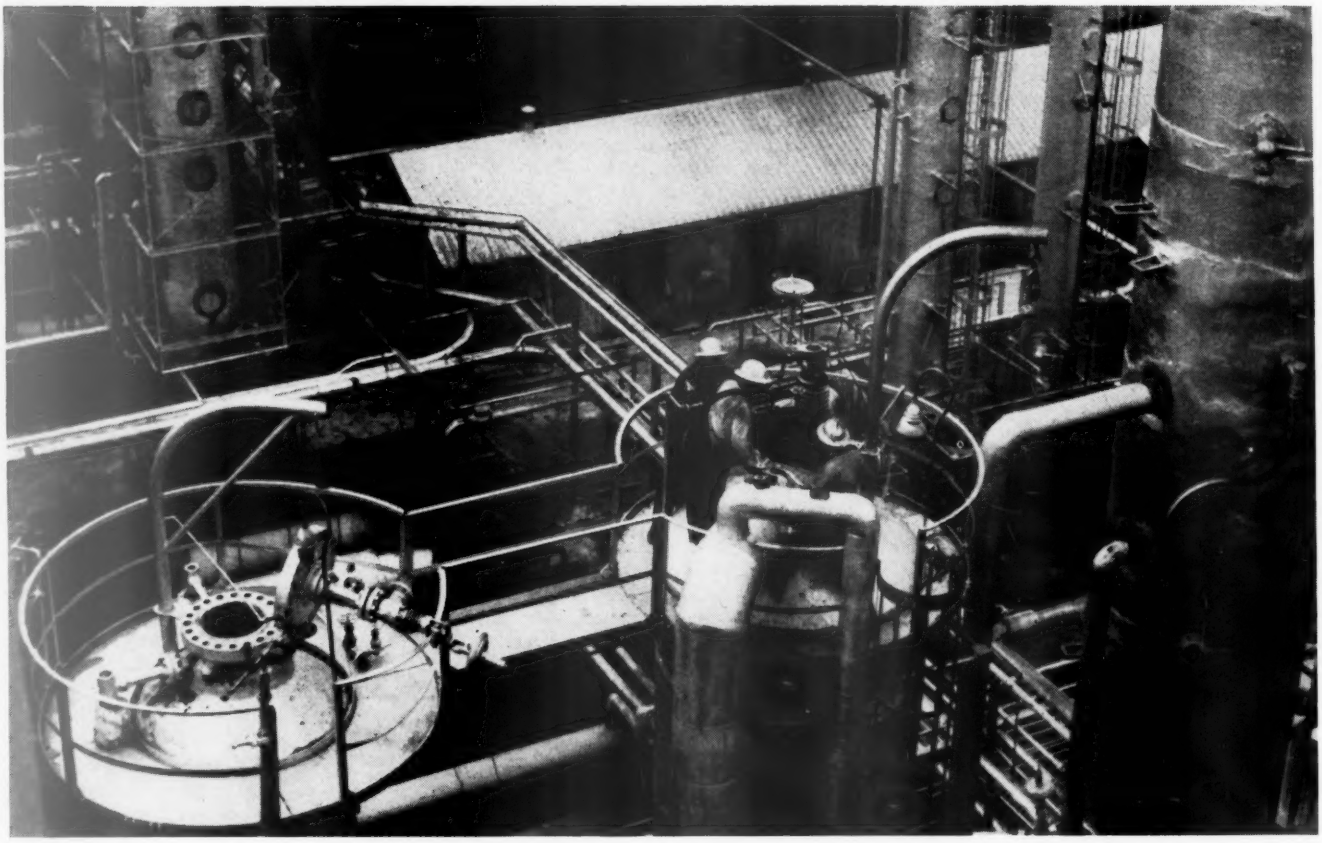


FIG. 8.

pering the return bends of the vaporizing heater tubes.

The Ingersoll-Rand wet gas compressors required thorough cleaning of both the power and compression sides. There were heavy sulphurous deposits on the suction valves of the compression cylinders from the hydrogen sulphide content of the gas processed. Actually, a large percentage of the 912 manhours charged by machinists during the turnaround was due to the maintenance required on the gas compressors.

The inspection of the gas and water separator tank revealed a slight pitting on those portions of the shell that are in contact with the water layer. This circumstance was corrected by sand blasting the lower half of the horizontal 10 by 40 separator and coating it with a protective plastic paint. This equipment is considered to be the most unconventional of the plant. Instead of passing the overhead vapors from the synthetic crude tower through conventional shell and tube condensers, a direct-contact, barometric type condenser is used. The cooling water and hydrocarbon streams are discharged into a tank where separation of the condensed gasoline and water takes place. In addition to providing many operating advantages, the inspection of this equipment indicated that a large amount of maintenance, material, and labor was saved over that which would have been expended with the regular type shell and tube condensers. Based upon the experience of other refiners, the amount of hydrogen sulphide in the overhead vapors would probably have necessitated retubing the bundles after eight months' operation. At the present time, it is fully expected that the barometric type condenser and the separator tank will last the life of the unit and require only very minor repairs.

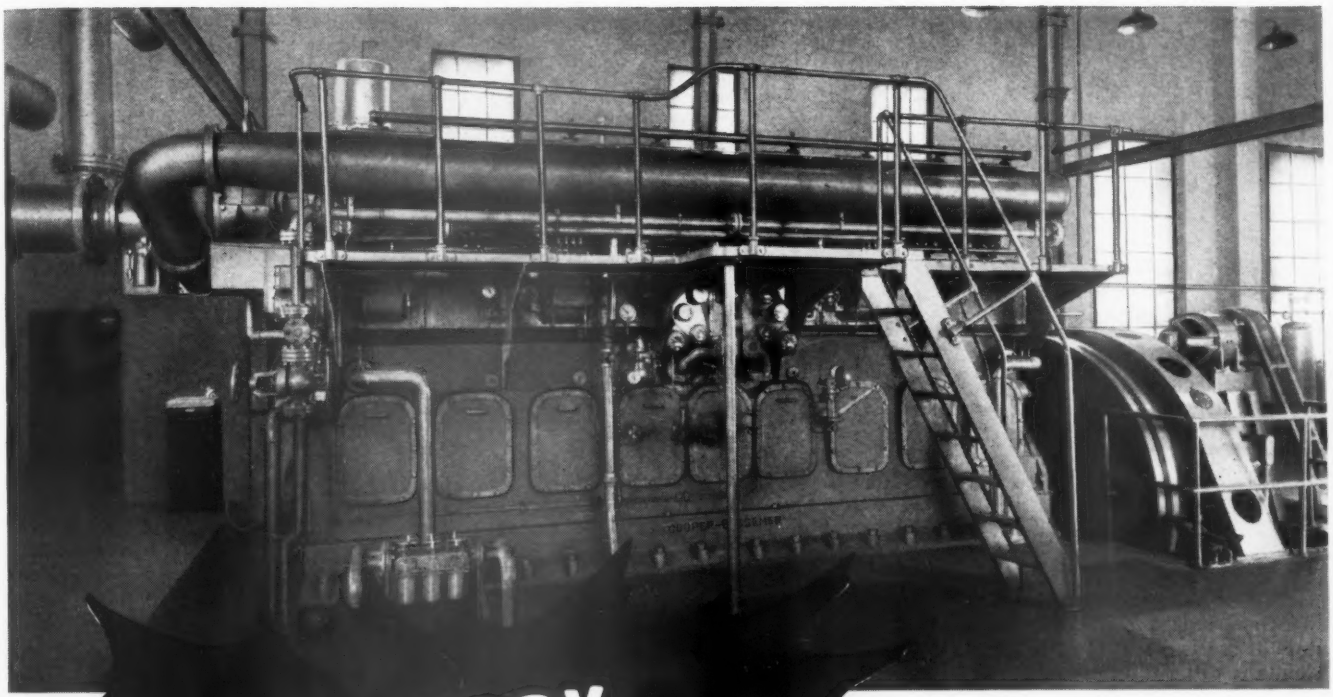
All fractionating towers in the plant were inspected and found to be in good condition. For example, there was practically no coke or catalyst fines in the bottom of the synthetic crude tower. This fact speaks well for the efficiency of the catalyst-vapor disengager in the bottom of the reactor since, for extended periods during the initial run, the charge rates to the reactor were considerably in excess of that for which the equipment was originally designed. The acidizing of the absorber was the only tower maintenance performed during the turnaround. Fig. 8 shows workmen engaged in removing the top head from the tar separator to permit inspection. A portion of the synthetic crude tower may be seen in the right foreground of the same photograph.

All coolers and heat exchangers were opened, inspected, and, when necessary, cleaned. There was not an excessive amount of fouling in any exchanger. The circulating quench exchangers were conspicuously free of any deposits of catalyst fines. The water sides of all water coolers were acidized.

A nominal amount of pump maintenance was required. Serious corrosion, similar to that which occurred in the hot tar lines, had also occurred in the hot tar pump, necessitating the replacement of fittings in the liquid end of the pump. Other pumps required routine servicing and some, because of their excellent performance during initial run, were not even opened for inspection.

There was essentially no instrument maintenance required during the turnaround. The tabulated data show a total of 220 manhours for instrument servicing, of which a large percentage was expended in replacing orifice plates in the plant to accommodate the higher charge rates that have been and will be maintained.

● **Conclusion.** Naturally, from the day discussions were initiated concerning the installation of a catalytic cracking unit, we at Leonard have been concerned about turnaround manhours because we knew we could not undertake shutdowns requiring the number of manhours consumed in previous inspections of catalytic cracking plants. Leon Harris, the maintenance superintendent of the Leonard organization, spent much of his time during the construction of the plant familiarizing himself with the unit and planning for the first turnaround. He was confident that it could be done with his own small force. Mr. Harris now states that he is certain that on a year around basis, the manhours of repair, maintenance, and construction on the catalytic plant will be considerably less than that formerly expended on the thermal unit. A very large share of the credit for such a satisfactory inspection and turnaround should go to Mr. Harris and all of his foremen. ★ ★



HISTORY IN THE MAKING

*One of several improved Cooper-Bessemer gas-diesel types now available, the engine at Cherokee is a supercharged, 8 cylinder, Type LS, rated 1440 bhp at 300 rpm. Power requirements are variable, with fractional loads about 75% of the time. The engine is direct-driving a 1000 kw generator.

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1. Cooper-Bessemer gas-diesels are highly practical for constant as well as *variable-load* service!

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The care and use of cable tool joints

By FERD J. SPANG, *President, Spang and Company*

A SUBSTANTIAL portion of the cost of the drilling of oil, gas, and artesian wells is represented in the unnecessary failure, in use, of the tool joints by which the different elements of the drill "string of tools" are attached to each other. Obviously these threaded components, commonly referred to as the "box" and "pin," are made to a considerable degree of accuracy and have certain mechanical qualities as well as limitations of strength and use.

EXCLUSIVE

Proper regard for these and other factors of use is essential if the life of tool joints is to be fully proportional to the service built into them. Such service may be extracted in useful work under proper care. Abuse, whether arising from lack of knowledge, from carelessness or expediency, will inevitably result in a shorter life and possibly cause costly delays and expensive fishing jobs.

It seems unnecessary to point out that all tool joints should be fully protected against corrosion and abrasion while not in use. A badly corroded tool joint can not be cleaned up to mate properly with another and eliminate existing defects resulting from corrosion that prevent proper interchangeability.

A tool joint that has been subject to abrasion to such a degree as to deform either its threads or its matching face will likewise cause some degree of damage to the one with which it is mated. While a protruding deformity may be removed, it is evident that a scarred or depressed surface can not be filled, and that in neither type of defect can the accuracy of a damaged tool joint be made to equal that of the original joint.

The threads of tool joints that have been damaged by stabbing the pin into the box out of alignment, or in a cross-threaded position (see Fig. 1), will usually be troublesome and frequently fail in service unless the damage has been rectified before they have been set up.

Two other factors of use should receive the careful consideration of the operator. One is that the size of the tool joint should be consistent with the work it must perform. It is a serious mistake to use small tool joints where larger ones may be used. The largest size that can be run in the hole and still leave proper fishing and fluid space should be used.

The other factor is that of tool joint tightness or the force as related to the wrench leverage and size. The force applied to tighten a tool joint should invariably be in proper relationship to its size. Even a casual study of failures indicates that the strength of the tool joint is quite frequently ignored by the user, and that it is the common practice of many operators to set them too tightly. Reasonable consideration paid to the strength of the tool joint when setting it up will avoid many premature failures.

By proper regard for the strength of the tool joints when they are set up and re-machining the joints at reasonable intervals, this type of failure can be practically eliminated.

The threads on tool joints having relatively low physical strength and high ductility will have a tendency to deform under excessive stress, whereas those having unusually high physical strength and relatively low ductility tend to form incipient cracks in thread root areas under similar stress. Obviously, tool joints having both reasonable ductility and strength are ideal. However, those that may be near to the extreme in either quality may give quite normal service if moderation is used in setting them up, while even those that have the ideal of strength and ductility will fail prematurely in service if over-stressed in setting.

In the matching of two tool joints the

FIG. 1. Threads of tool joint may be damaged when pin is not aligned in box.

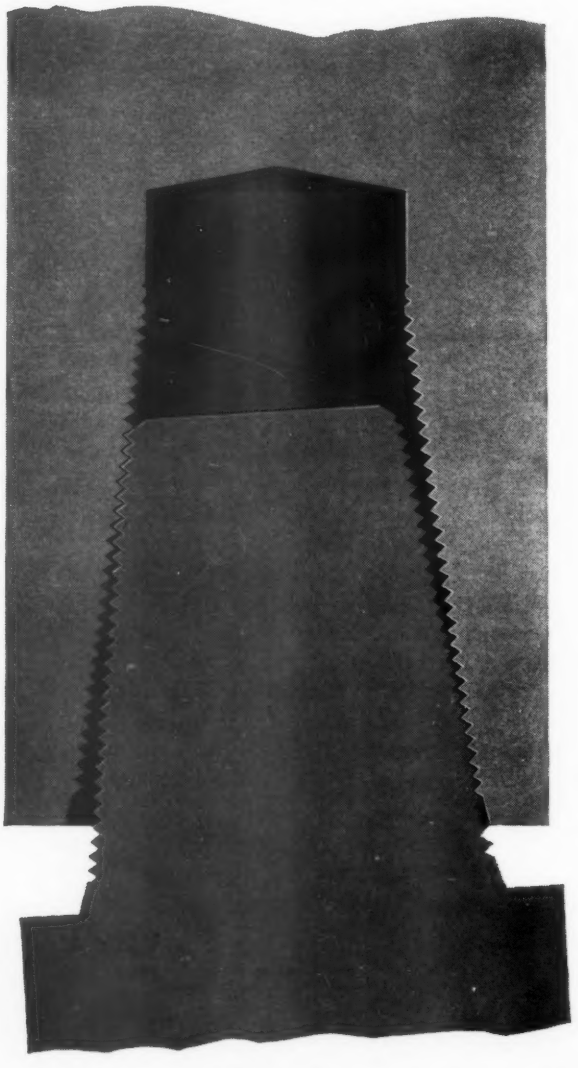

FIG. 2.

FIG. 3.

correctness of the thread lead or pitch of each as related to the other is of paramount importance. The lead is the measure of the advance of the pin into the box for each turn around its axis. When tool joints are set too tight the pin tends to stretch and the lead to increase. The threads in the box next to the open end are thus deformed and drawn toward the box face, causing a lead error in the threads of the box. Thus lack of proper consideration paid to the strength of the joint in setting it results in the loss of thread lead accuracy, thereby interfering with the interchangeability of new and old joints. On the other hand proper consideration given to joint strength, the lead of the joint thread will, for all practical purposes, be preserved and failures arising out of the mating of accurate new tool joints with old ones having bad off-pitch thread lead will be materially lessened.

The matching of a tool joint having a lead error with one having a correct lead causes stresses that result in the formation of incipient cracks at the base or root of the thread in either the pin or the box, or both. Peak stresses resulting from high frequency vibrations, originating with the tool impact, tend to dampen out when they reach these incipient cracks. As the peak stresses of these vibrations can not be liberated in such a limited area within the physical strength of the steel, these incipient cracks develop, widen, and grow through grain-cleavage destruction as a progressive fracture until the remaining sound steel is not of sufficient strength to carry the load with the result that either a ring is broken off the box or the pin will be jumped off. (See Figs. 2 and 3).

The galling of both the threads and the faces of tool joints is another problem that may or may not reach the point to which it is known to the operator. Minor galling of the threads of a tool joint apparently takes place with considerable frequency and takes some toll of broken pins and boxes. Unless it is of such a degree as to interfere with screwing up to shoulder of the tool joints, its presence is seldom recognized.

Likewise, galling of the tool joint face is never considered serious unless it results in a leaky joint. Galling, either in the threads or on the tool joint face does interfere with the driller's judgment of the force he is using to set up the tool joint. Consequently it has much bearing on the successful use of tool joints.

Excessive or large galled areas are the exception rather than the rule. (See Fig. 4). The infrequency of their occurrence, the variation of the areas and their nature indicate that they result from conditions of use rather than from design, defects in material, or finish. That galled areas can be avoided by proper care in use has been proved down through the years from the time when faggoted Norway iron was first used as the material from which tool joints were made, until the present, when the use of heat-treated steel is the common practice.

In considering this problem one must first understand the mechanical and metallurgical action that takes place in the production of a galled surface, either on the face of the joint or on the threads.

The fitting of two machined surfaces together under extreme pressure, such as the setting up of a joint, results in the development of both friction and heat between the two surfaces.

In the event of any abrasion, a raised surface or spot, or the presence of a foreign, gritty substance at one or more points, the pressure and friction with its resultant heat is totally localized in these small areas.

This localization of concentrated pressure, friction, and heat results in a minute portion of the steel on one or the other or on both surfaces taking on marked hardness commonly known as cold-work hardness.

At this first stage a small portion of extremely hard steel acting as a core is embedded in a mass of malleable-like material. This core in turn attaches itself, either by merchanical cleavage or by welding, to the mating or opposite surface by which it is motivated through its own embedded area. As it moves forward in this embedded area it grows in size by the additional attachment of parts of its own embedded area that in turn take on similar cold-work hardness. Thus, there is no limit to the size to which the core will grow, except the area of the surface in which it is embedded. (See Fig. 4.) As the core with its matrix rolls or slides forward, it produces a scar in the mating or opposite surface, which also enlarges as it grows in size in its own embedded surface area, thus ruining both tool joints.

The formation of such a core and matrix is not to any considerable degree dependent upon either the chemical or physical properties of the steel in which it is formed. It is normally harder in a hard steel than in a softer steel, but the hardness of the core and the hardness of the embedded area, or matrix, have similar proportional relationships to each other.

The next point to consider in the study of the problem is to determine and eliminate any condition that might be present that would result in localizing friction and pressure on a small area that would in turn result in the concentration of heat and movement of a small particle, perhaps 1/32 in. or less in diameter, and would cause the formation of the initial core and matrix.

Steel is a crystalline substance and

consequently, when it is finished by cutting it with a keen cutting tool the resultant surface is the "cross grain" of a fiber-like mass that exposes, on the finished face or surface, the cores, or partial cores, or crystals, embedded in a ferrite mass. After machining, this resultant surface is polished, but there is no way by which the mass face may be compressed or set into a tightly knit homogeneous surface to meet the necessary working conditions except by applying pressure and movement of the mating surface, with some form of lubricant between them.

The spasmodic application of pressure to these two surfaces before they have developed a cooperative homogeneous mating fit and face hardness, invites the concentration of pressure and frictional heat in the presence of irregularities, scars, or foreign substances.

The breaking-in of the joint is therefore the most important factor in the prevention of galling and extreme care is necessary to avoid it and thus insure the proper life of the tool joint with satisfactory mating behavior.

There are, of course, a number of conditions to consider from a mechanical standpoint. The full tightening of the tool joint either with or without a lubricant may move a small speck or whisker of steel, just one particle, out of its place and roll it into a hard core and matrix that would grow in size as pressure and movement are applied between the two contacting surfaces.

A scar on a thread or on one mating face caused by abrasion in the handling of the tool joints prior to assembling them, a rusty wire bristle from a thread brush, a speck of emery left by an emery stone embedded in one of the surfaces, or sticking to it, will result in extensive frictional heat and possibly develop a hard core. Minute substances in hard water used to wash the joints frequently contributes to the forming of galls.

There are, of course, numerous other conditions and other foreign particles that could cause the formation of hard movable cores with their matricies that if not removed or polished to face level before tightening the tool joint will ultimately lead to extensive galling.

Among these latter conditions is that of the careless manner in which the pin is stabbed into the box by some users. It is not an uncommon practice of some operators to stand the drilling bit up on the floor, put some back twist in the cable and then lower the stem box down over the bit pin and spin the stem box onto it.

Tool joint threads are small and have a lead of only 1/7 in. per rotation. Consequently, even if the stem and the bit were held in perfect alignment, the 3 in. taper per foot would permit a support of only 0.018 in. of the point of one thread on the point of the mating thread. (See Fig. 5.) If the weight of the stem should be allowed to come to rest on this thin narrow thread point, it would shear a wire from one or the other approximately equal to the combined area of nine average human hairs. This would be bound to happen unless the timing of the bull wheel or drum break was so perfect as to prevent such an engagement. Obviously, if the stem and bit are not held in perfect alignment, the threads would be matched in a cross-threaded position and the rotation of one would saw through the threads of the other and possibly shear some slivers from the tops of the threads of each. (See Fig. 1.)

When a sliver is sheared off a thread it takes on cold hardness. In fact, it will be about as hard or harder than ordinary spring steel wire of the same cross-sectional area. As there is no place for this sliver to go except between the threads, the result is that when the threads are set up this sliver will start a gall. As this gall moves forward it grows in size through the adhesion of the nucleus or core to the surrounding steel or matrix as already described.

Proper tool joint stabbing can be done with the use of a swivel wrench. With it the tool is supported on a leverage and in balance so that when it finds the mating position of the pin threads inside the box threads, there is little or no effective force beyond that necessary to balance and move the tool as it is rotated into threaded engagement. The result is that there is little likelihood of damaging either thread. It is possible, however, that even with a swivel wrench

FIG. 5.

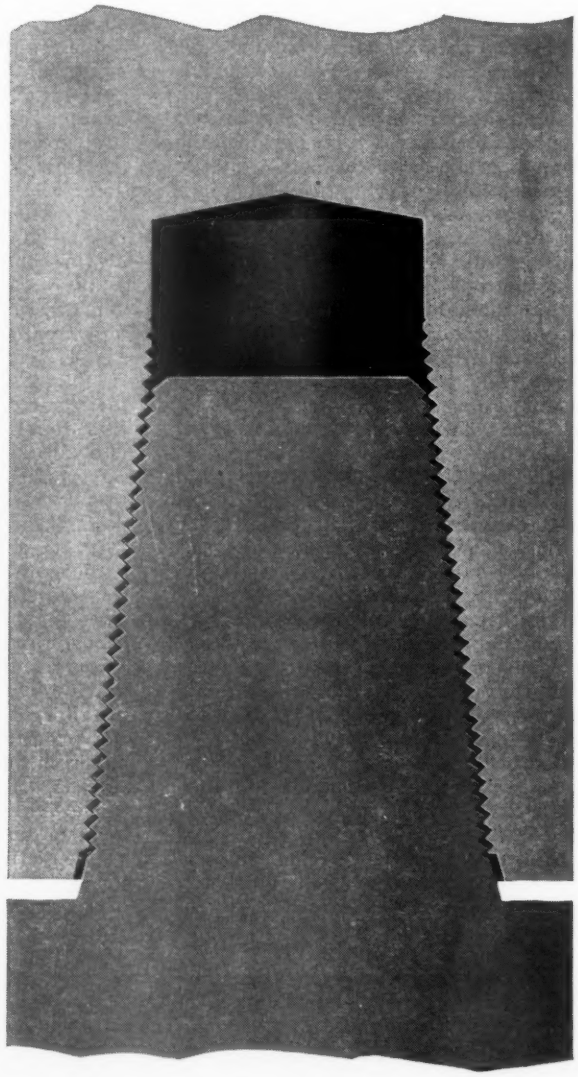

FIG. 4. Large galled areas result from conditions of use.

Baash-Ross News

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OUR 28th YEAR

It's BAASH-ROSS... FOR EVERYTHING IN SQUARE KELLYS!

All Sizes—All Designs—All Lengths

PLUS the Most Advanced Construction and Metallurgical Features!

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In fact, Baash-Ross provides everything in square* Kellys!

They have Everything in Performance Features!

● Baash-Ross Square Kellys are forged end-to-end from one solid piece of restricted analysis, fine-grained alloy steel, with each heat of steel individually checked for quality by separate test specimens.

● After forging and before heat treating, the dimensional accuracy of the forged square section is checked by an API Kelly Sleeve Gage which must pass freely over the entire length of the square to check maximum allowable tolerances across flats and across corners. Also, accurate caliper measurements are taken to make sure no portion of the driving section is undersize!

● Next, a series of heat-treating operations performed over the *entire length* of the Kelly in one operation, develop the metallurgical properties of the steel to provide the *best balance* of shock-resisting toughness and wear-resisting hardness.

● Additional heat-treatments harden the threaded ends for maximum life and service.

● All residual forging stresses are relieved by these heat-treating processes, thus eliminating the most prevalent cause of bending and deformation.

● The Kellys are then carefully bored by precision drilling machines so that the bore is precisely centered end-to-end, then double-checked by highly-accurate survey devices. For products with bores 2¼" diameter or larger, wall thickness of the Kelly *must not* vary more than one-*sixteenth* inch for each 10 ft. of product length, or fraction thereof.

● The Kelly itself is also accurately surveyed for straightness and *must* be straight within one-*eighth* inch when measured at any point over its entire length.

● The alignment of the projected axis of each threaded end, when checked with the precise Baash-Ross Alignoscope, *must* be within one-*eighth* inch of the longitudinal axis of the Kelly for each 10 ft. of Kelly length, or fraction thereof.

● In addition, threads *must* pass, not only all API specifications, but also unusually rigid Baash-Ross specifications on thread form, taper, lead, finish, etc.

The above highlight only a few of the many controls maintained by Baash-Ross to insure absolute straightness, long-life and maximum all-around performance from every Baash-Ross Kelly!

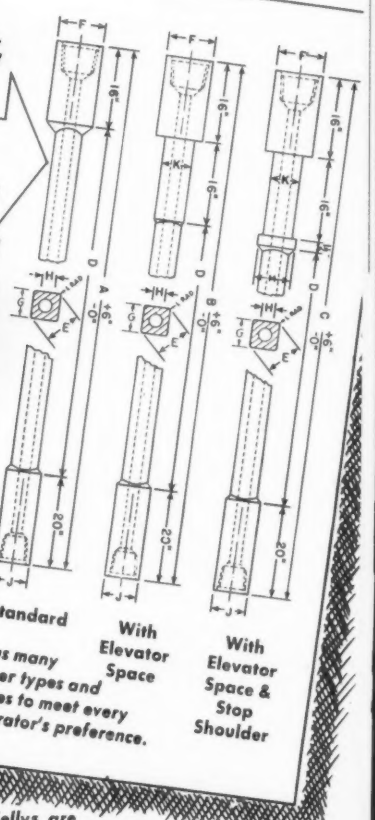
They are Available in

..All Sizes ..All Designs

Baash-Ross "Trubore" Forged Upset Square Kellys

Nominal Size In.	Overall A Ft.	Overall B Ft.	Overall C Ft.	Working Length D Ft.	Top Upset Joint Size A.P.I. Left Hand In.	Top Upset O.D. F In.	Bottom Upset Joint Size A.P.I. Right Hand In.	Bottom Upset O.D. J In.	Bottom Upset I.D. H In.	Bore Across Corners E In.	Across Flats G In.	Elevator Space O.D. K In.	Elevator Space Corner Radius L In.	Stop Shoulder O.D. M In.	† Cu. Ft. per Lin. Ft.
2½	35 40	36–4 39–4 41–4	36–6 39–6 41–6	32 35 37	4½ Reg. 4½ Reg.	5¼* 7¾	2⅜ Reg. 2⅜ I.F.	3¼ 3⅜	1¹⁵⁄₁₆ 1¼	3¹⁵⁄₃₂	2⅝	2¹³⁄₁₆	8⅛	3⅜	*.165 .327
3	35 36 40	36–4 39–4 41–4	36–6 39–6 41–6	32 35 37	4½ Reg. 4½ Reg.	5¼* 7¾	2⅜ Reg. 2⅜ I.F.	3¼ 4⅛	1¹⁵⁄₁₆ 1⅝	3¹³⁄₁₆	3	2¹³⁄₁₆	⅜	4⅛	*.165 .327
3½	35 38 40	36–4 39–4 41–4	36–6 39–6 41–6	32 35 37	4½ Reg. 4½ Reg.	5¼* 7¾	3½ Reg. 3½ F.H. 3½ I.F.	4⅛ 4⅜ 4⅝	2⅛ 2⅜ 2¾	4¹³⁄₃₂	3⅝	3¹⁹⁄₃₂	⅝	4⅞	*.165 .327
4¼	35 35 40 54	36–4 39–4 41–4 55–4	36–6 39–6 41–6 55–6	32 35 37 51	4½ Reg. 6⅝ Reg.	5¼* 7¾	4½ Reg. 4½ F.H. 4½ I.F.	5¼* 6⅛ 6⅝	2¾ 3⅛ 3⅜	5⅜₁₆	4¼	4¹⁹⁄₃₂	⅝	5⅛	*.165 .327
5¼	35 40 54	39–4 41–4 55–4	39–6 41–6 55–6	35 37 51	6⅝ Reg.	7¾	5½ Reg. 5½ F.H. 5½ I.F.	6⅝ 7⅜ 7⅞	3⅜ 3¾ 3¾	6²⁹⁄₃₂	5¼	5⅝	⅝	7	.327
6	35 40 54	39–4 41–4 55–4	39–6 41–6 55–6	35 37 51	6⅝ Reg.	7¾	6½ Reg. 6⅝ F.H.	7⅜ 8	3¾ 3¾	7⅛	6	6⅜	¾	8	.327

Sizes shown in RED are A.P.I. standard
* Alternate 5¾ inches O.D.—.180 cu. ft. per lineal ft
† Volume based on largest diameter of kelly



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**The Baash-Ross lines of Hexagon and Octagon Kellys are equally complete. Write for data.*

a tool joint may be stabbed in a cross-threaded position. (See Fig. 1.) When this does happen, the operator should remove the pin from the box and look it over to see that no damage has been done. In no case should the operator attempt to straighten up a cross-threaded tool joint by force. The leverage that is possible in a bit several feet long when applied to a shear plane of approximately 0.018 in. wide is enough to shear it off and leave a splinter between the threads.

The final factor in the problem of galled tool joint threads and faces and absolutely necessary to its solution is proper preparation of them before applying excessive pressure and friction, and in continuous watchfulness against allowing a small gall to roll far enough to form a larger and more troublesome gall.

New tool joints should be very thoroughly cleaned and then lubricated with a clean lubricant such as machine oil. They should then be put together and hand snapped up with the wrenches without using the circle jack. They may be snapped up so tightly with the wrenches that it may be necessary to use the sledge on one of the wrenches to snap them apart. This procedure should be repeated about three or four times, after which the joint should be taken apart, thoroughly cleaned, and carefully examined. If a small gall is present, it can be removed without difficulty at this stage. It may be removed by stoning or cutting it out with the point of a small chisel or scraper and subsequently slightly stoned.

The excessive use of a whet stone or the use of coarse commercial emery stones on tool joint faces is dangerous, as is also the reckless use of a file. A soft whet stone may safely be used in moderation to remove the film of waste impurities that result from setting the tool joints, but they should not be used really to whet the steel away, for that will remove the burnished surface.

After the tool joints have been carefully cleaned, examined, and re-cleaned, they should again be lubricated and put together. This time they should be set up rather lightly with the circle jack, after which they should be taken apart again, re-cleaned, and re-examined. The setting, taking apart, cleaning, and re-cleaning should be repeated until the set up action has a definite stop point, which indicates that the tool joints have "come home" and are in proper condition for use.

They should now be taken apart, thoroughly re-cleaned, and wetted with water, and set up tight enough to run, provided there is no indication of creep. In the event there is an indication of creep, they should be taken apart and examined, re-cleaned, and reset. A creeping joint indicates that it has not "come home" or that a gall is forming. If a gall is forming, it should be found and removed before it becomes dangerously large.

In the breaking-in of new joints, it may be just as well to use oil, casing thread dope, or soft soap as it is to use a lubricating oil; but extreme care must be taken to keep any lubricant clean. Hard water may be made more lubricative by the addition of a small amount of Gold Dust or any similar soap-like material.

In the resetting of used tool joints, such as in changing bits, extreme care should be taken to wash the exterior of the box after it has been pulled out of the hole to prevent small particles of sand from dropping down onto the face of the box prior to the setting of the tool joint. Real cleaning of the outside of the box can not be done by merely dropping the water pipe in alongside of the stem or otherwise washing it as it is withdrawn from the hole. The outside of the box should be washed by putting a bucket of water up over it and rubbing the outside of the box to free it. It should then be rewashed by dousing it with clean water. Very few people have good enough vision to see small silicious grains of sand on the dull gray surface of a tool joint face, hence, the procedure and not the vision should insure the absence of foreign particles.

Reviewing the breaking-in of the joint as outlined above, here are the steps: First, lubricate the joints and apply slight pressure between the mating surfaces, then separate them, clean and re-lubricate them. Re-set them with slightly more pressure. Repeat as often as is necessary to bring them "home" to a proper fit. Finally re-clean them, wet with water, and set them with enough pressure to make up the joint for use. The purpose of this is to wear and compress the two mating surfaces into a matched and balanced relationship with each other so that the final pressure may be equal and applied uniformly over all the surface and not be concentrated in small localized areas in any excessive degree.

Each piece of machinery has its own characteristics and no matter how good it is, it does have some slight irregularities. Otherwise it would be unnecessary to wear in engines, or grind valves, or be cautious in the use of new machinery. This same rule applies to some degree in the matching of cable tool joints. Wearing and burnishing the two surfaces together by degrees will produce matched surfaces that will have enough hardness to give a long and satisfactory life.

Thus if the very slight errors in machining are erased through step by step breaking-in of the joint, the total stresses arising in use may be spread over the total area to which the force is to be applied, with the result that neither galls nor minute localized fissure cracks or fractures are a problem.

The summation of the subject is this: Care in the handling, storage, stabbing, and breaking in of cable tool joints, together with a proper regard for their strength, will result in a considerable saving to the operator. Such saving will be realized through extended life of the tool joints, in the reduction of delays, and through the reduction of the number of fishing jobs. Caution used in the breaking in of the joints and in the subsequent setting of them will reduce or eliminate galling and at the same time lessen the likelihood of premature fatigue breakage. The total result will be not only a saving of cost to the operator and a lessening of physical labor to those who perform the work, but also the creation of a greater amount of good will from those for whom the drilling is being performed. ★ ★ ★

How to determine flow of steam through a given opening

ONCE in a while a question along the following lines is put to this writer: Can you give me a reliable rule for determining the weight of steam that flows out of an open pipe or hole from a high pressure boiler directly into the atmosphere in a given time?

A reliable and remarkably simple rule that has been used for many years is based on Napier's formula, as follows: "To the steam gauge pressure in pounds per square inch add 14.7; then multiply that sum by the area of the opening in square inches; and divide that product by 70." The result is the weight of steam in pounds flowing through the opening every second.

So that any reader can apply the above rule to steam losses in his own plant and get a dollars and cents answer here is a practical form: "To the steam gauge pressure in pounds per square inch add 14.7; multiply by the area of the opening in square inches; multiply that by the cost of the fuel in dollars per ton (2000 lb.3; multiply that by 0.257; and into the result divide the number of pounds of water evaporated into steam in the boiler per pound of fuel. The result is the cost of the steam in dollars per 10-hour day.

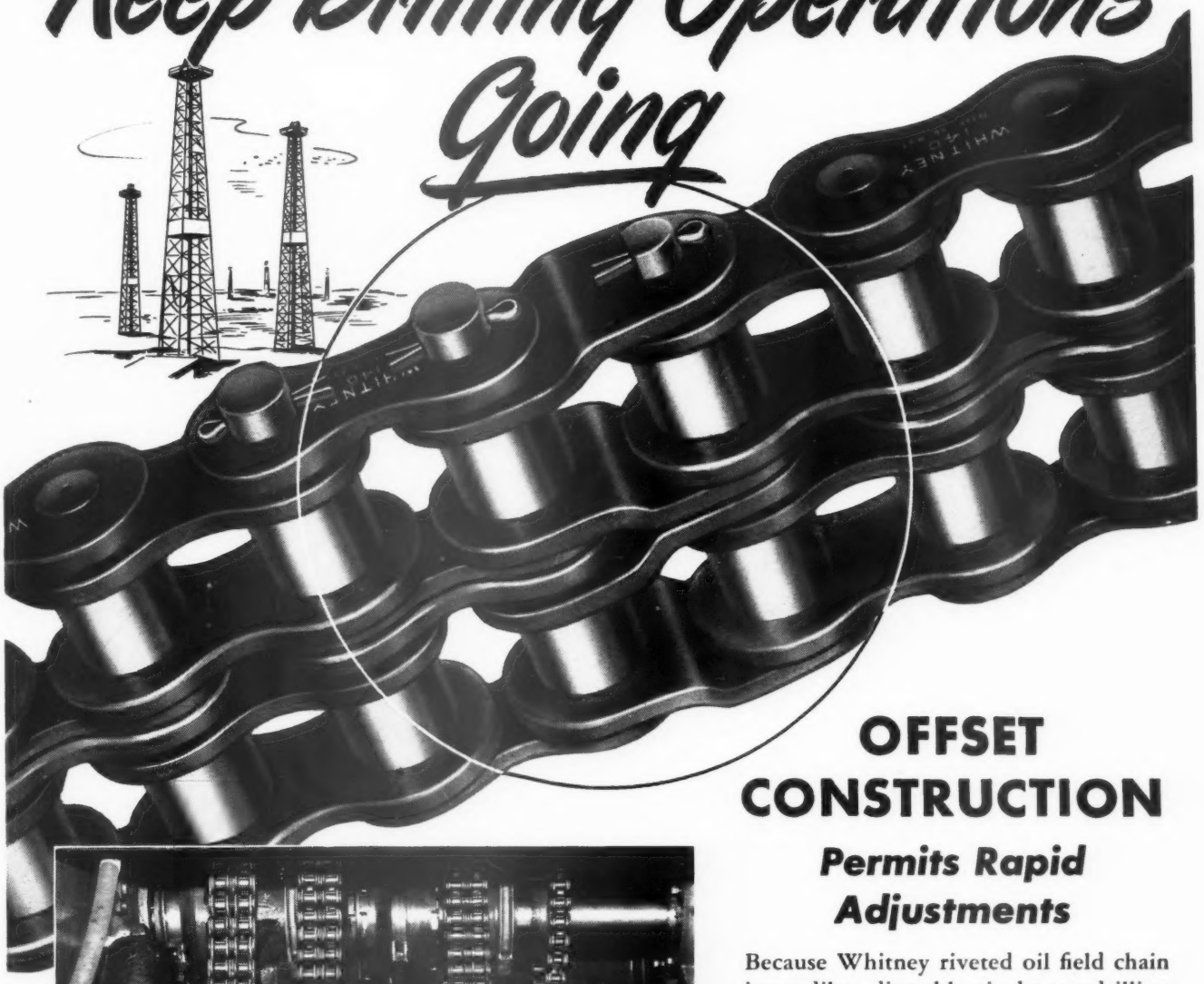
Thus for example, what is the cost of steam per 10-hour day flowing through a ½-in. round opening into the open atmosphere? The gauge pressure is 100 lb. per sq. in.; fuel costs $8 per ton; and 8½ lb. of water are evaporated into steam per pound of coal.

By means of tables it is easy to find that the the area of a ½-in. round opening is 0.196 sq. in. Or, without tables it can be computed in this way: $\frac{1}{2} \times \frac{1}{2} \times 0.7854 = 0.196$. Then substituting in the above rule we get $5.44 as the cost of the steam per 10-hour day.

This writer has a high regard for Napier's formula because, a number of years ago he checked it carefully in a university engineering laboratory and he found that it gave remarkably accurate results.—By W. F. SCHAPHORST.

WHITNEY OIL FIELD ASSEMBLY CHAINS

Keep Drilling Operations Going



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Because Whitney riveted oil field chain is readily adjustable, it keeps drilling operations going at top speed.

Should it become necessary to adjust the chain for normal wear, all you do is remove one or more of the *offset links,* which are spaced at regular intervals, and you're ready to keep drilling. There is no waiting for replacement links, no tough repair work. And remember, because you simply remove a link or two from the original Whitney Chain, equal pitch on all links is maintained.

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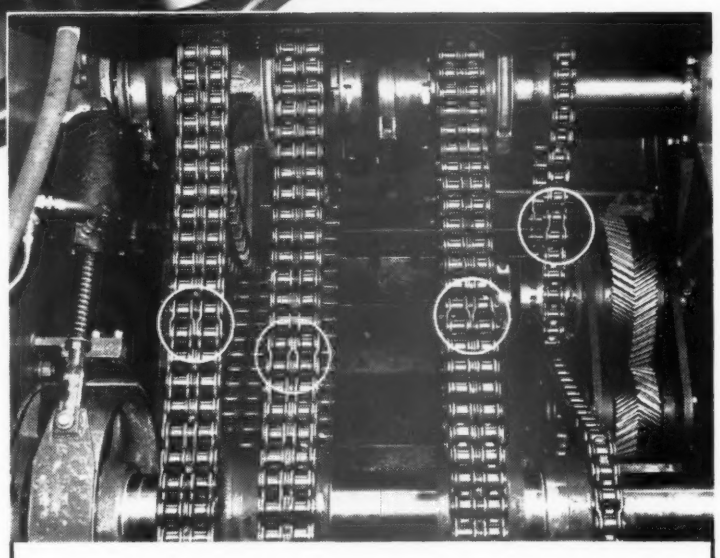

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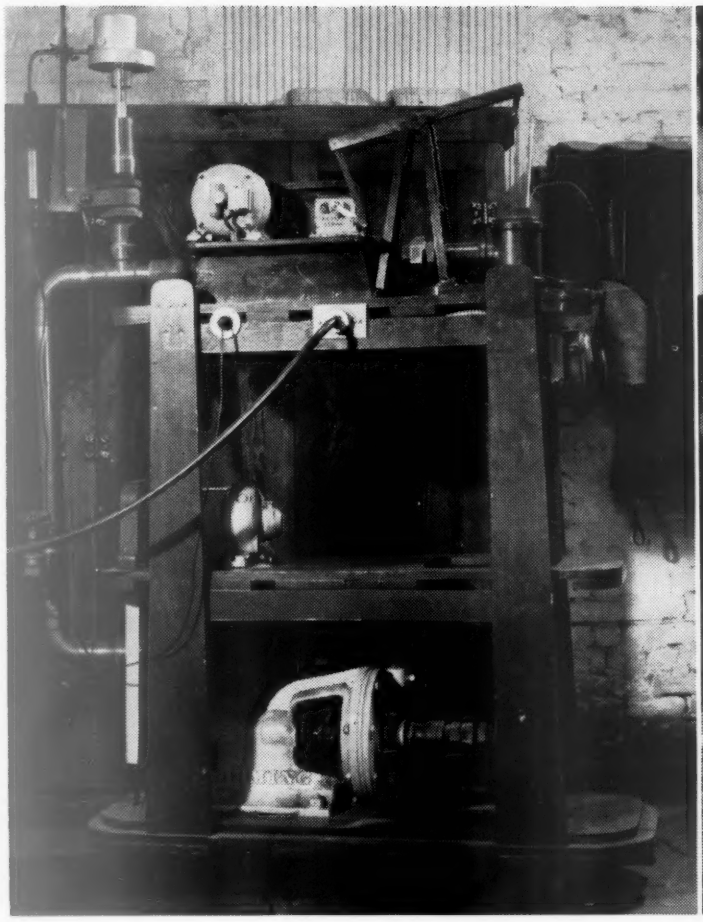

FIG. 1. Side view of recirculator for drilling mud.

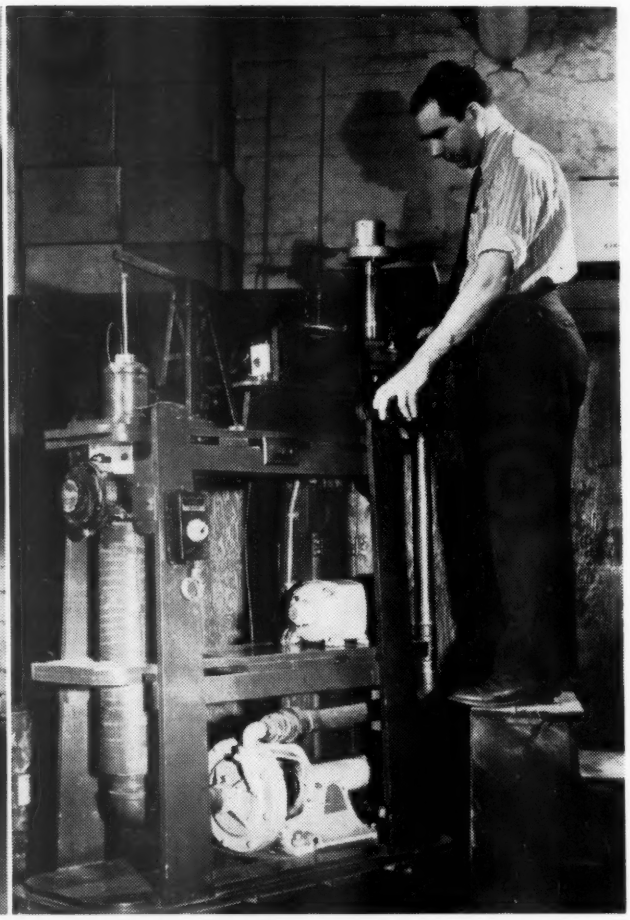

FIG. 2. Operator in position to take viscosity readings.

Chemical treatment of drilling mud

By NORMAN E. MARTELLO, Research Engineer, Calgon, Inc.

ALTHOUGH the art of chemically treating drilling mud for viscosity reduction has been practiced for several decades, the laboratory testing methods that are still relied upon for evaluating the effects of various chemicals are quite similar to those used when the art was initiated.

The literature is replete with information concerning the use of new instruments for evaluating the properties of mud, but very little has been written about the methods of processing the mud in the laboratory prior to testing. In general, the procedure consists of taking a known amount of mud, treating it with chemical agents, and determining with the aid of testing equipment the effect of these agents. In many cases the muds are treated and tested at room temperature; in others, the muds are treated and heated in sealed containers for periods of time prior to testing at room temperature. These methods, although of value in obtaining a relative picture of the mud behavior while it is quiescent, overlook the fact that in well drilling the mud is being agitated and heated concurrently for considerable periods of time. Changes in the clays and the ordinary treating chemicals by complex reactions involving base-exchange, hydration or dehydration, absorption or desorption are thus accelerated in well drilling, giving in many instances results that differ from those shown by the clays and chemicals under ordinary static testing.

In order to approximate more closely the behavior of mud in actual field operations, an apparatus (see Fig. 1) was devised and built in which the mud can be heated and circulated continuously for extended periods of time. Chemicals can be added to the mud while it is circulating and their effect on the mud can be studied in about the same way as is done in actual field practice. The viscosity can also be checked periodically without the necessity of removing mud from the apparatus. This results in a twofold advantage; no sampling of mud is required, and the tests can be run for longer periods, for no mud is withdrawn from the apparatus.

Two differences exist between this laboratory system and the systems used in field operations. In field work a reservoir of mud is always kept on hand to maintain the circulation of mud if some of it is lost to the formation penetrated, to permit settling of the sand carried to the surface from the bore hole, and to allow for any contingencies where an extra quantity of mud may be needed. No reservoir was incorporated in the laboratory system because of the possibility of channeling, which would lead to unequal treatment and incomplete circulation of the mud stream. Also, as the laboratory apparatus is a completely enclosed sys-

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Airflex Principle Gives You Top Flexibility of Power Control

The "giant's grip with a feather touch" has amply proved the money-saving advantages of the Airflex principle on drilling rigs. That's why leading manufacturers now use Fawick Airflex clutches on modern oil field equipment.

Fawick clutches provide the exact degree of grip or slip required regardless of load or inertia. They give you instant, automatic, positive control of power at the flick of an air valve.

Fawick clutches transmit torque through friction blocks carried on a rubber-and-fabric tube actuated by air pressure. Both prime mover and driven unit are protected against unnecessary breakage, undue wear and tear and needless down time.

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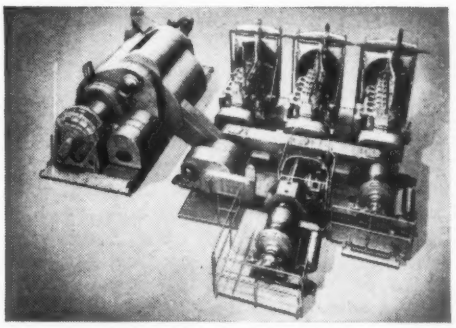
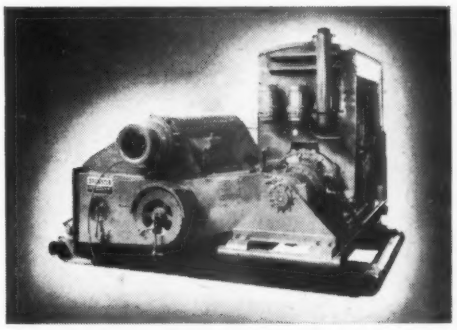
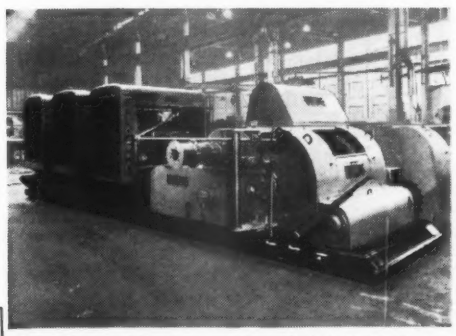


Oil Well Supply Co., No. 96 Hoist and No. 1000 Triple Engine Drive, with 9 Fawick clutches.



Brewster Co. Model N-4 Rig, equipped with 3 Fawick clutches.



Unit Rig and Equipment Co. Model U-15 Rotary Rig, with 3 Fawick Engine Clutches.

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Compressed air expands the rubber-and-fabric gland to engage clutch with any degree of "grip" you want. Release the air and clutch disengages.

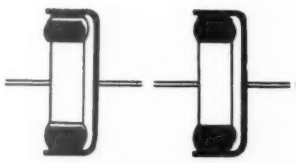

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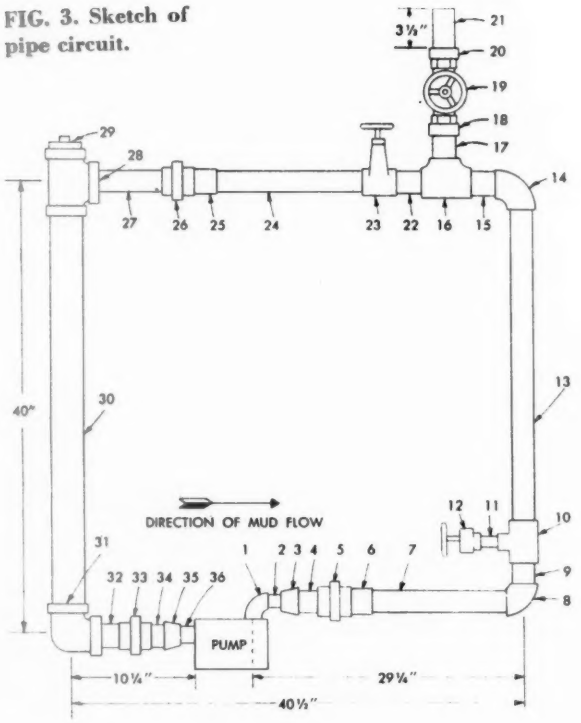
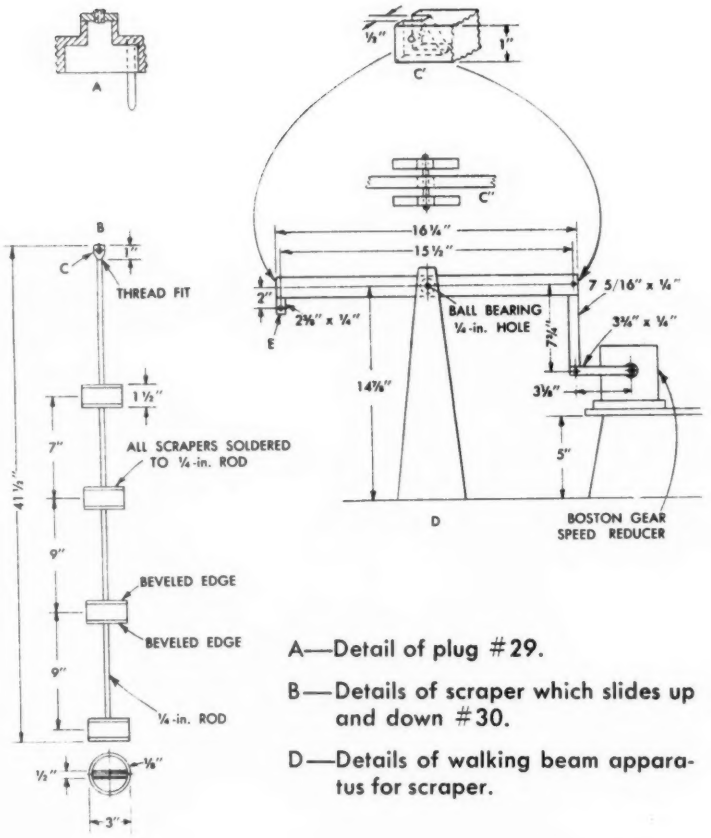
FIG. 3. Sketch of pipe circuit.



LIST OF PARTS

1—1" Service elbow
2—1" All thread nipple
3—2" x 1" Reducing coupling
4—2" All thread nipple
5—2" Ball joint union
6—2" Copper to iron pipe male adapter
7—2" Streamline pipe
8—2" Streamline 90° elbow
9—2" Streamline nipple
10—2" x 2" x 1" Streamline tee
11—1" Streamline nipple
12—1" Scott 125 gate valve
13—2" Streamline pipe
14—2" Streamline 90° elbow
15—2" Streamline nipple
16—2" x 2" x 2" Streamline tee
17—2" Streamline nipple
18—2" Copper to iron pipe male adapter
19—2" Powell new ready valve
20—2" Copper to iron pipe male adapter
21—2" Streamline nipple
22—2" Streamline nipple
23—2" - 2 Scott 125 gate valve
24—2" Streamline copper pipe
25—2" Copper to iron pipe male adapter
26—2" Ball joint union
27—2" Nipple approximately 5½"
28—3" x 3" x 2" tee
29—3" Plug
30—3" Copper pipe
31—3" x 2" 90° Reducing elbow
32—2" All thread nipple
33—2" Ball joint union
34—2" All thread nipple
35—2" x 1½" Reducing coupling
36—1½" All thread nipple

FIG. 4. Scraper and walking beam drive.



A—Detail of plug #29.

B—Details of scraper which slides up and down #30.

D—Details of walking beam apparatus for scraper.

tem, a reservoir of mud was not considered necessary for evaluating the effect of chemical treatment. Generally, a certain amount of contamination is introduced from the formations penetrated by the drill bit. This contamination varies considerably from well to well and from formation to formation in any given well. In the laboratory pilot unit, all contaminating materials are added to the original mud used in the test work. Satisfactory comparison of the effect of two chemicals on a contaminated mud can be obtained by adding the contaminant at the beginning of the test instead of a little at a time throughout the test.

The apparatus, which is designated as a recirculator, consists of three principal sections: (1) A large centrifugal pump for circulating the mud, (2) a heated section through which the mud flows, and (3) a valve arrangement for trapping a mud sample so that the viscosity can be determined. The entire mud system is made of copper and brass, minimizing the corrosion that would result from the use of iron. To facilitate movement, the outfit is mounted on a platform supported by dolly wheels. For cleaning, the circulating system can be separated at two union connections, one on the top horizontal run and the other on the bottom horizontal run of the pipe sections. Difficulties due to the sticking of hot mud on the inside of the heated pipe are eliminated by the up and down movement of a scraper that traverses the whole heated section. Capacity of the system is about 2.6 gal and the mud is circulated at an approximate rate of 20 gpm.

For measurement of the mud viscosity (see Fig. 2), a Model LV Brookfield viscosimeter equipped with a variable speed drive is employed. Spindle rotation rates of 6, 12, 30, and 60 rpm can be obtained by turning a switching device. The instrument is operated with a synchronous motor and comes completely standardized. It has a 1½-in. guard around the spindle, which gives sufficient

TABLE 1. Construction details.

1. Heater construction:
   Copper pipe (No. 30) is covered with several layers of asbestos paper. Chromel C wire is then wound over the paper. Wire covers full length of pipe. One piece of magnesia pipe covering is then placed over the wire. The covering is taped on and then painted.
2. Scraper construction (Fig. 4):
   The individual scrapers are made of brass tubing beveled at both ends. They are attached to the brass ¼-in. rod by copper strips. The copper strips are bolted to the scrapers and then the strips are fixed to the rod by soldering. The coupling at the top of the scraper rod is threaded so that it can be removed when the plug A is slipped over the rod during assembling.
3. Lifting apparatus (Fig. 4):
   A 2¼-in. chain driven sprocket is attached to the motor and a 3-in. sprocket is attached to the speed reducer. The motor and speed reducer are placed 7¾ in. apart from center-to-center of the sprockets. A light chain is used to drive the reducer. The scraper makes about 6¼ complete strokes per minute while operating.
4. Pipe apparatus (Fig. 3):
   All pipe and fittings are either brass or copper to eliminate corrosion. Only the pump casting is iron. All streamline pipe and fittings are soldered together. Threaded pipe and fittings are screwed together.
5. Framework construction:
   All framework for support of component parts is of wood and the whole is mounted on dolly wheels to facilitate movement.
6. Pump apparatus:
   The ⅓-hp motor has a V-belt 4-in. pulley attached to the shaft, and the pump has a 6-in. pulley attached to the shaft. A ½-in. V belt is used to transmit power to the pump.
7. Plug [(Fig. 4(A)]:
   The plug is drilled on the top and a brass bearing is soldered into the plug to guide the scraper rod as it slides up and down. On the side of the plug two wells are soldered in, one for the thermometer and the other for the thermoregulator.

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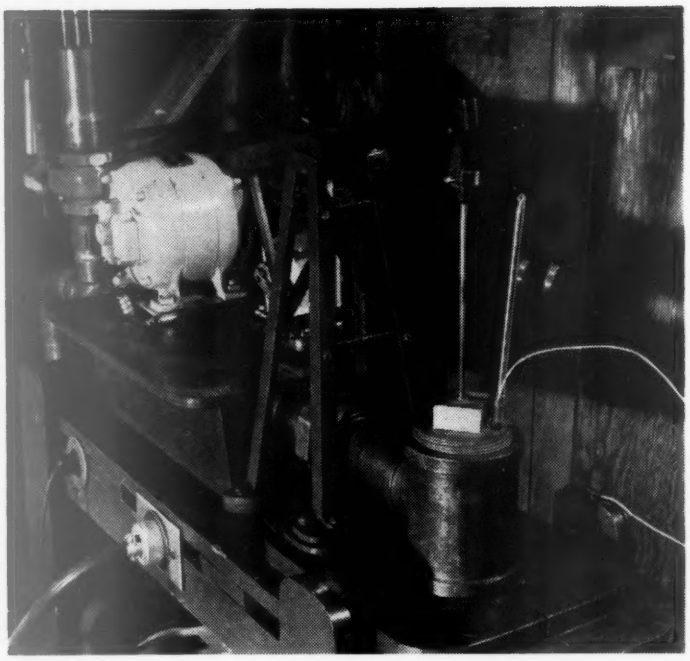
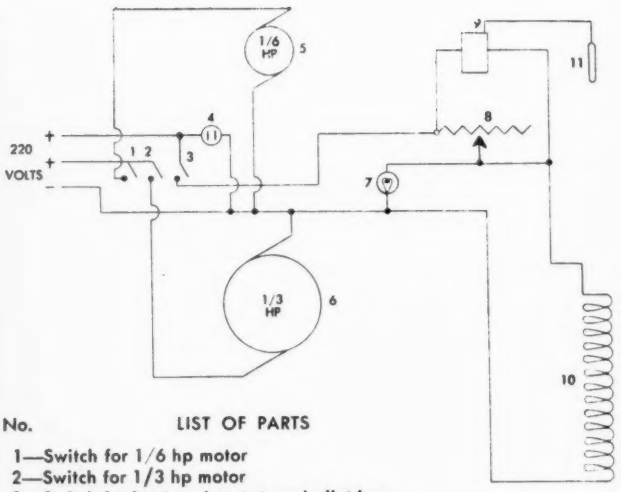


FIG. 5. Closeup of scraper assembly actuating mechanism.



No. LIST OF PARTS

1—Switch for 1/6 hp motor
2—Switch for 1/3 hp motor
3—Switch for heater, rheostat, and pilot lamp
4—Female plug for Brookfield viscosimeter
5—Motor for operating scraper arrangement
6—Motor for operating pump
7—Pilot lamp for heater
8—Rheostat for controlling current to heater
9—Thermoregulator for controlling temperature
10—Heater around copper pipe No. 30
11—Thermoregulator bulb for temperature control

FIG. 6. Electrical wiring diagram.

clearance for immersing into the mud cup. The No. 3 spindle rotating at 12 rpm was used for obtaining all viscosity measurements recorded in this investigation.

● **Construction details.** A schematic sketch of the piping arrangement is shown in Fig. 3. Leading from the pump outlet is a service elbow (1), which is connected to a union (5) by a nipple (2), a reducer (3), and another nipple (4). The union (5) is attached to the pipe section (7) by an adapter (6). An elbow (8) joins the one end of the pipe section (7) to a nipple section (9), which in turn is soldered to a tee (10). The small side outlet of the tee (10) is connected by a short nipple (11) to a gate valve (12), through which a sample of mud is withdrawn at the beginning and the end of the test. The other outlet of the tee (10) is joined to an elbow (14) by a pipe section (13). This elbow (14) connects to a tee (16) by means of a short nipple (15). The upright end of the tee (16) is attached to a short nipple (17), an adapter (18), and a quick acting valve (19), which is used to shut off the flow of mud into the cup. Above this valve is an adapter (20) and a nipple (21) both of which go to make up the cup in which the mud is retained while its viscosity is being determined.

A standard gate valve (23) used for throttling the mud flow is connected to one end of the tee (16) by a nipple (22) and to a union (26) by means of an adapter (25) and pipe section (24). The union (26) is joined to the tee (28) at the top of the heated pipe (30) by means of a nipple (27). The top outlet of the tee (28) is closed by a plug (29) through which the scraper rod slides, while the bottom outlet is joined to the heated pipe (30). A reducing elbow (31) connects the bottom of this heated pipe (30) to a union (33) by means of a short nipple (32). The union in turn is connected to the pipe inlet by a nipple (34), a reducing coupling (35), and a short nipple (36). All fittings, pipe, and valves from the adapter (6) to the adapter (25) are soldered together whereas the remaining fittings and pipe are all screwed together. For ease in cleaning, the circuit is taken apart by unscrewing the unions (5) and (26). The one whole section of piping can then be removed and flushed out with water. By unscrewing the plug (29) and removing the scraper, the heated section (30) can be cleaned by brushing and flushing with water.

The second schematic sketch, Fig. 4, shows details of the scraper unit, and Fig. 5 shows a close-up photograph of the scraper assembly actuating mechanism. For assembling the scraper in the apparatus, the section (B) is slid into the pipe section (30). The coupling (C) is removed and the plug (A) is inserted on the rod of the scraper. The coupling (C) is then screwed on the scraper rod and attached to the end (E) of the walking beam assembly by a bolt. The plug (A) is screwed into the tee (28) and the unit is now ready to operate.

TABLE 2. Equipment description.

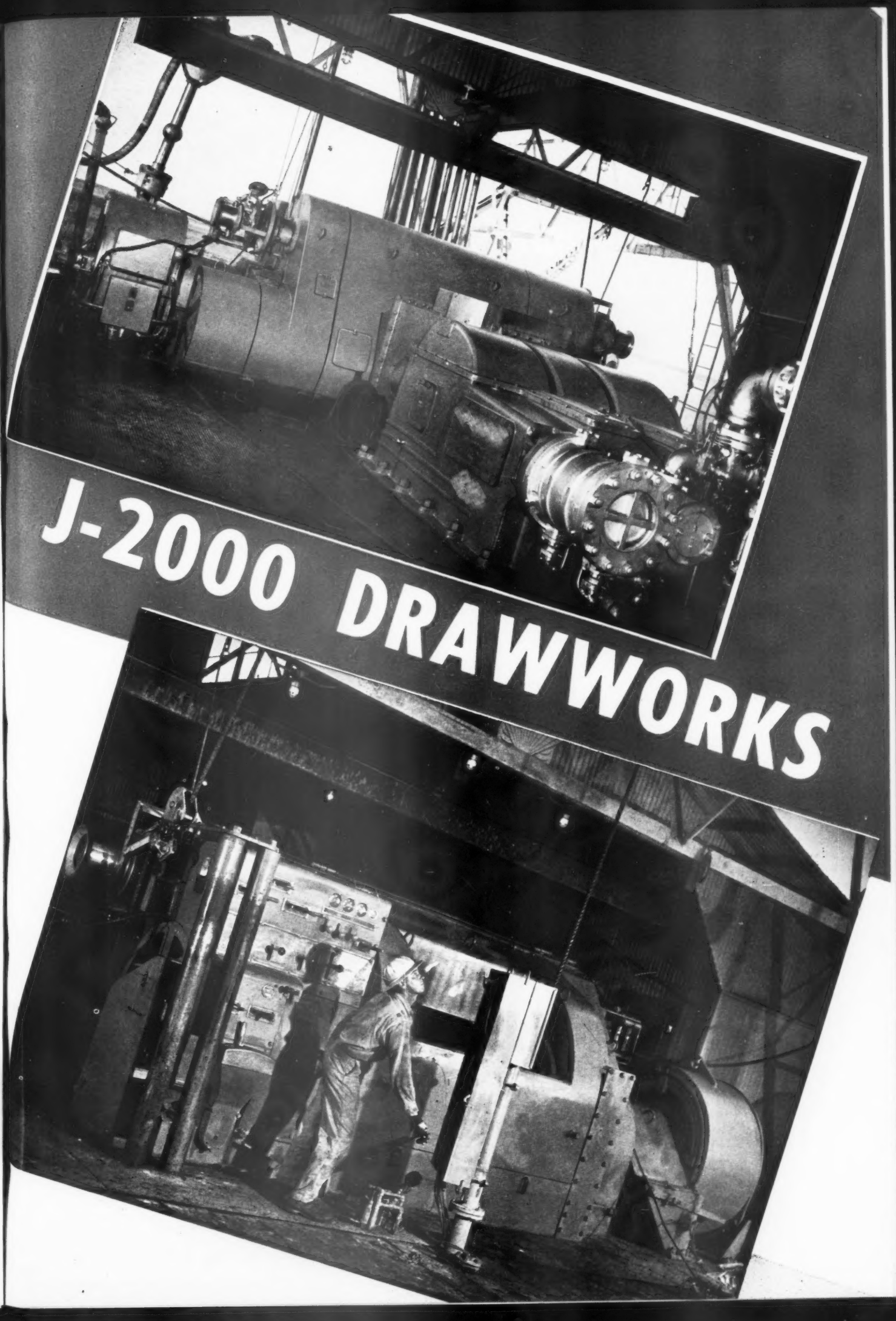
1. Deming-Mueller centrifugal pump No. 4012-1 with bronze impeller. From The Deming Company, Salem, Ohio.
2. Boston gear speed reducer, Model LA200.
3. ¼-hp General Electric continuous duty motor, 110v., a.c.
4. ⅓-hp Leland White continuous duty motor, 110v., a.c.
5. Thermoregulator—From Edwin L. Wiegand Company, Pittsburgh, Pennsylvania. AR-2504 Style 4 Serial No. AC. 633.
6. Heater—Wound from Chromel C ribbon Wire 1/16 in. wide 0.504 ohm/ft. AWG 25 Heater draws 5.5 amp Wattage 643 Approx. 42 ft. wire used.

The electrical wiring diagram of the apparatus is shown in Fig. 6. This drawing shows three switches, one for the pump motor (6), another for the walking beam motor (5), and a third for the heater (10). Control of the heat input is accomplished by adjusting the thermoregulator (9) and the rheostat (8). Once the thermoregulator (9) has been set, control within ½ degree can be held by slight adjustments of the rheostat (8).

Tables 1 and 2 list details of the construction of the various units of the apparatus, as well as a description of some of the equipment used.

● **Testing procedure.** Prior to the beginning of a test, the apparatus is thoroughly cleaned and assembled, with the exception of the scraper and plug (A) over the heated pipe. A weighed quantity of mud then is poured into the recirculator through the top of the heated pipe. The total quantity of mud necessary to completely fill the apparatus varies with the mud weight, but generally amounts to about 12.8 kg or 28 lb. With the apparatus filled, the scraper is inserted into the heated pipe and the plug is screwed over the top. The scraper is connected to the walking beam by the coupling (C); the thermoregulator and thermometer are placed in wells situated on the plug, and circulation with heating and scraping is begun.

After the mud temperature has risen to 176 F, viscosity measurements are obtained by the following method: With the valve (19) open, the valve (23) is slowly closed. The mud flow is throttled and the mud rises into the cup above the valve (19). When the mud is within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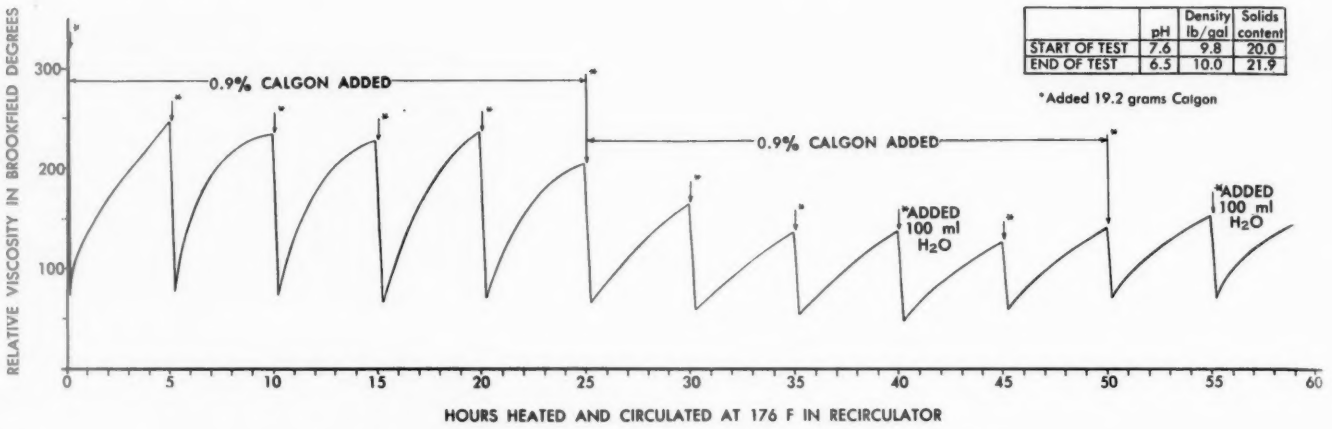

FIG. 7. Effect of Calgon on a salt cut mud in a recirculator test.

an inch of the top of the cup, the quick acting valve (19) is closed and the rotating spindle of the Brookfield viscosimeter is immersed to the proper level in the mud. Viscosity readings are taken and recorded. The valve (23) and then the valve (19) are completely opened. This permits the mud to flow back into the recirculating system, after which the valve (19) is closed. The cup and viscosimeter are cleaned and are ready for reuse. A small mud sample is now removed through the valve (12) and retained for comparison with a sample to be taken at the end of the test.

Chemical treatment is now ready to be started, so the scraper is stopped in the up position and the plug (A) is unscrewed and lifted from the top of the heated pipe. The weighed chemical in a dry form is introduced into the circulating mud, followed by about 100 ml of water for rinsing out the chemical container. The plug is replaced on the heated pipe and the scraper is again started. After a 5 min period, viscosity readings are again taken using the procedure described.

Circulation and heating of the mud are continued with viscosity readings being taken ½ hr after chemical addition and at 1 hr intervals thereafter up to 5 hr. Chemical is again fed in the same manner as described above, and viscosity readings are taken at quarter, half, and one-hour intervals after the feeding of reagent. These 5-hr cycles are carried on throughout the test, which may last for at least several days if the chemical used continues to treat the mud satisfactorily. If this is not the case, the mud will thicken up to such a point that the test must be stopped. Good comparisons of the practical life of various chemical treatments can thus be obtained. This time cycle was adopted because the mud thickened up sufficiently in 5 hr to make the feeding of chemical desirable. Several times during each test 100 ml portions of water are added to help make up for the loss due to evaporation from around the scraper rod. These water additions have very little effect on lowering the viscosity of the mud. At the end of the test a sample of mud is again withdrawn through the valve (12) and saved. Both mud samples, one from the beginning and the other from the end of the test, are checked for pH, mud weight, and solids content. In this way the changes in these mud properties can be followed. It is obvious that this pilot unit permits considerable latitude in the method of testing, particularly with respect to the mud temperature employed and the frequency of chemical additions. Also, by means of the four-speed arrangement on the Brookfield viscosimeter, apparent viscosities may be determined at any one of the four rates of shear. With this viscosimeter it is possible to follow the rate of gel of the mud by taking readings with every revolution of the spindle over a short time period. This can only be done at 6 rpm, and 12 rpm, for at the higher rotation rates continuous readings cannot be taken while the spindle is in motion.

● **Example of chemical treatment.** Fig. 7 shows a plot of the values obtained by treating 12,800 g of a mixed mud composed of 0.5 per cent bentonite, 9.5 per cent ordinary drilling mud clay, 9.5 per cent barite, and 0.35 per cent sodium chloride with Calgon* over the entire testing period. The concentrations of all ingredients were based on the total mud weight. The pH was 7.6 at the beginning of the test and 6.5 at the end. No alkali agent was added during testing so that the drop in pH was presumably due to partial rehydration of the Calgon or to sequestration of calcium ions from the water and clay. Both the density and the solids content increased a little from start to finish, the density rising from 9.8 lb per gal to 10.0 lb per gal, with the solids increasing from 20.0 to 21.9 per cent. These values indicate that the mud lost water by evaporation during the 59-hr test period.

The initial addition of 19.2 g of Calgon, which is equivalent to 0.15 per cent of the total mud weight, markedly decreased the viscosity of the original mud. As heating and circulation were continued, the mud thickened up. After 5 hr, a second increment of Calgon again reduced the viscosity, which subsequently rose again as heating and circulation were continued. After a total of about 1.0 per cent of Calgon had been added, the mud began to show progressively less increase in viscosity during the successive 5-hr periods. Even after 2 per cent of Calgon had been added, the increase in viscosity during each cycle was small indicating that considerably more chemical could have been added before the original viscosity conditions would be reached.

*A soluble complex sodium phosphate glass with a guaranteed minimum content of 67 per cent P_2O_5 and impurities including water of less than 0.25 per cent when made.

● **Summary.** The construction and operation of a laboratory pilot unit for testing the effect of chemical treatment on drilling mud has been described. Tests conducted with this recirculating apparatus embody the features of circulation and heating that are present in every field operation. For the evaluation of chemical treatment, the test periods can be made long enough under conditions approximating field operations so that a good comparison can be obtained between a specific treatment in the laboratory and an actual drilling operation. By means of this pilot unit it is practical, therefore, to check various chemical treatments in the laboratory and obtain results that make it possible to know beforehand how a given treatment will work in the field.

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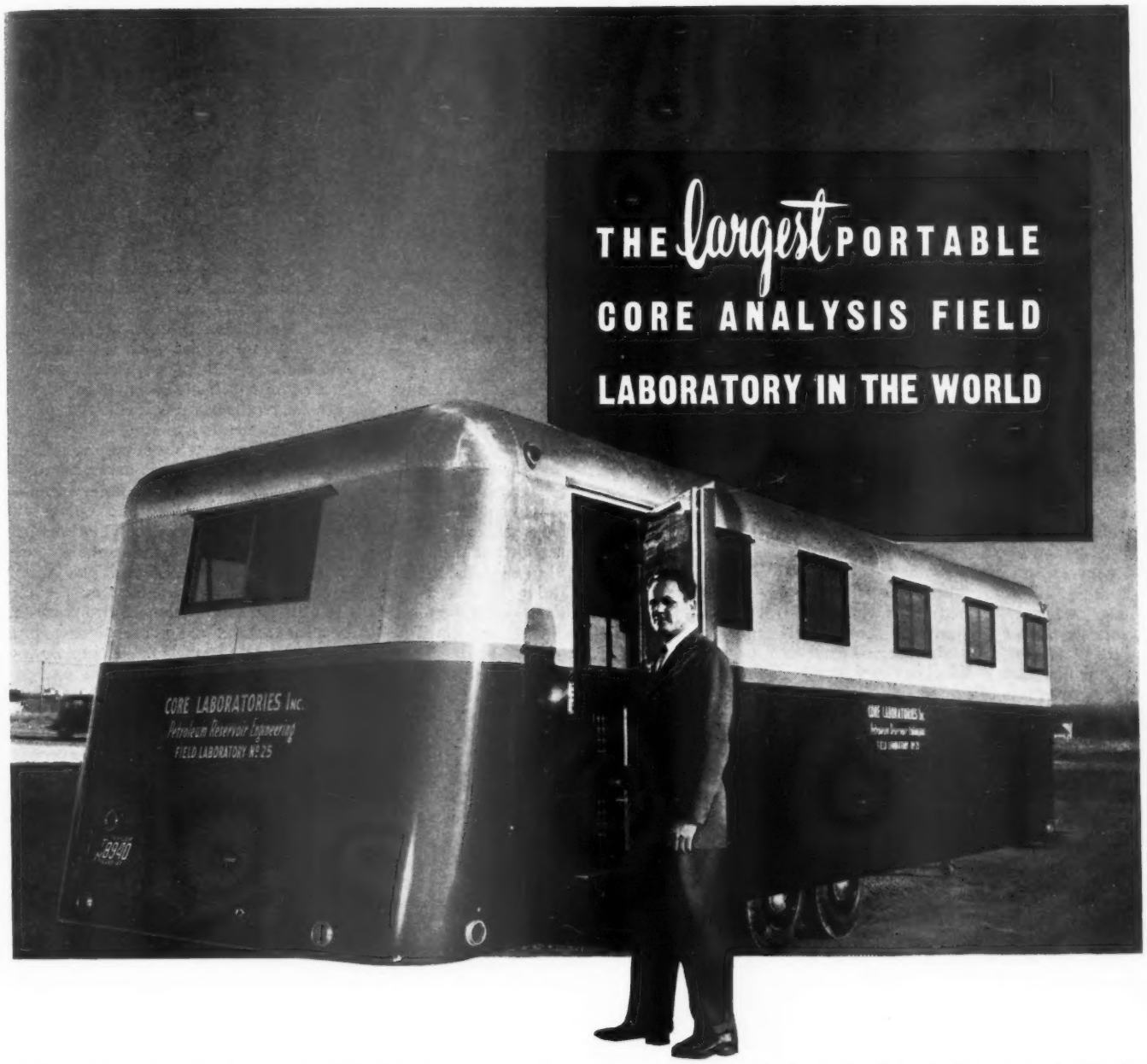

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Part 10. Fractionation Fundamentals—Two Component Systems

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EXCLUSIVE

THE process of separating a mixture of two or more volatile substances into its component parts by partial vaporization of liquid and condensation of vapor with repeated revaporizing and recondensing until the desired degree of separation is obtained is known as "fractional distillation" or "rectification" or just plain "fractionation" or even "distillation" This process may be carried out batchwise with frequent redistillation of various cuts; or it may take place continuously by countercurrent multiple contacting of vapor and liquid, thereby affecting simultaneous partial condensation of vapor and vaporization of the liquid. This study will be devoted to the continuous rather than batch distillation because the former is of more practical importance in the hydrocarbon industries. Batch distillation was covered in a previous installment.

Continuous rectification consists of simultaneous fractional vaporization and fractional condensation, in other words, it consists of a series of equilibrium single contact phase separations, the feed for each separation being a colder liquid from the plate above and a warmer vapor from the plate below. The equilibrium vapor from each of these separations will be richer in the more volatile components than the vapor feed to the contact, whereas the equilibrium liquid will be richer in the less volatile components than the liquid feed to the contact.

The basic concepts of fractionation were discussed in Parts 1 and 2 of this series, where simple figures were included to illustrate the description. See Figs. 3, 4, and 5 of Part 1 and particularly Figs. 14, 15, and 16 of Part 2. In Parts 3 and 4 vaporization-condensation fundamentals and calculation methods were presented. The theories and practices covered by these earlier chapters are of direct interest in this and subsequent chapters on fractionation. In this, the tenth installment of the series and the first of several on continuous fractionation, the fundamentals of fractionation will be covered by considering binary systems.

The simplest of all continuous rectification operations requiring process design calculations is that of a two component mixture. A thorough understanding of the mechanism of binary distillation and of the calculation method provides a foundation upon which to base the study of the more complex multicomponent distillation operations such as hydrocarbon fraction as practiced in the petroleum industry. The basic principles are the same regardless of the number of components but in the case of the two component mixture the mathematical treatment is much simpler than in more complex mixtures. Several broad generalizations can be developed from a study of two component mixtures that are applicable to multicomponent mixtures. For example: The effect of vapor-liquid flow pattern is more easily analyzed for binary systems. Also the graphical methods developed for binary systems may be applied to multicomponent systems by proper adjustments of the equilibrium or operating lines.

Two of the well known empirical process design methods for multicomponent fractionation are based on a correlation of the results from many graphical calculations on several binary mixtures. For this reason, as well, two component rectification is the place to start a study of fractionation intended to include the various multicomponent design methods.

DESIGN PRINCIPLES

The four basic principles of all process design calculations are: (1) *Material balance*, (2) *heat balance*, (3) *equilibrium*, and (4) *rate* of material and heat transfer. In fractionation design these fundamentals are usually applied by means of the theoretical equilibrium stage (or plate) concept, as most commercial columns are of the bubble plate type. Bubble plate efficiency and capacity will be discussed in later articles. In this chapter the discussion will be concerned with theoretical equilibrium stages rather than actual plates.

With a theoretical stage, the equilibrium part of the design involves finding vapor and liquid quantities and compositions for given conditions by flash vaporization type calculations, and it includes estimating temperatures by bubble and dew point calculations on equilibrium liquids and vapors. These equilibrium calculations are described and illustrated in Parts 3 and 4 for single isolated equilibrium phase contacts. For multistage equilibrium contacting of vapor and liquid phases, the basic principles are the same but the calculations are much more complex. In addition to *multi* components there are *multi* stages.

Of equal importance to the phase equilibria estimates in fractionation calculations are the material balances. Component and overall material balances are made on individual stages, on sections of the column, on the whole tower, and on the entire system, as required in the calculations. Material balances are so fundamental and *obvious* that there is not much that needs to be said about them. The important trick is to manipulate material balances for *multi* components and *multi* stages in conjunction with the equilibrium calculations for the same components and stages.

In most hydrocarbon fractionation calculations, heat balances enter as auxiliary computations of secondary importance insofar as the theoretical plate and component distribution calculations are concerned. Heat balances are used to determine the internal liquid and vapor quantities and/or to determine the duties of the reflux condenser and reboiler. In most cases it is possible to assume a constant L/V ratio for the section or use the terminal L/V values at the ends of the section. Heat balances are involved in estimating L/V ratios at different points.

In this respect it is not necessary to combine heat balances with the *multi* component and *multi* stage equilibrium and material balance calculations. Such a three-way calculation would be very complex. For two-component systems, heat balance and equilibrium relationships may be used instead of material balance and equilibrium relationships; however, the additional work of this design method is only justified where the L/V ratio varies, which might be caused by the enthalpy relationship for the mixture or by the manner of heat removal and the heat losses.

Heat and material balance relationships are termed "operating line" relationships, specifying the interstage flow of liquids and vapors. Heat balances may be one of the primary calculation steps or they may constitute a secondary step in the process design of a fractionator. In addition to being a part of the theoretical plate and component distribution calculations, heat balances are involved in sizing auxiliaries, such as reboiler and condenser.

The fourth of the basic principles listed above, rate of material and heat transfer, is involved in sizing equipment but not in making the theoretical plate and component distribution calculations. Rates will be discussed later.

FRACTIONATION APPARATUS

Fractional distillation of a mixture of two or more hydrocarbons is carried out in a bubble plate column with auxiliaries, such as shown in Fig. 39. This is a typical fractionation system although there are numerous variations on each item of equipment, such as reboilers, condensers, bubble plates, etc. The equipment details will be discussed later.

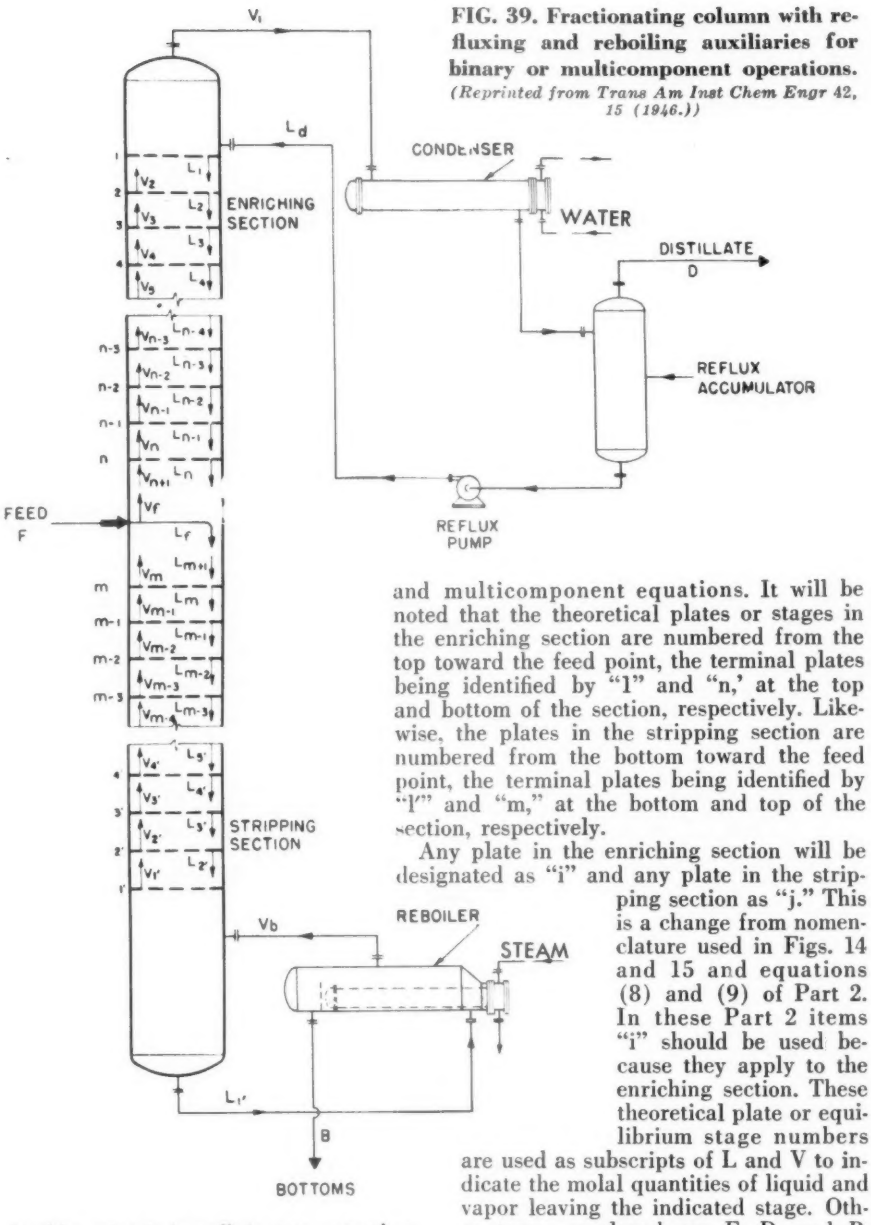

FIG. 39. Fractionating column with refluxing and reboiling auxiliaries for binary or multicomponent operations. *(Reprinted from Trans Am Inst Chem Engr 42, 15 (1946.))*

At this point it is sufficient to note that the feed may enter at any point between the top and bottom and at any condition between subcooled liquid to superheated vapor. The point of feed entry divides the column into *enriching* and *stripping* sections. For the purposes of this chapter the theoretical equilibrium stages may be bubble cap trays or perforated plates of any satisfactory design. It will be noted that the condenser and reboiler each act as an equilibrium plate so that the streams (liquid reflux and reboiled vapors) returned to the tower are in equilibrium with the net products (overhead distillate and bottoms residue). These conditions need not be thus in practice. The reflux may be of the same composition as the distillate and the reboiled vapors may be of the same composition as the bottoms liquid. Fractionation equations will be based on the apparatus shown in Fig. 39. Slight modifications in the mathematical or numerical results correct for different refluxing and reboiling hookups.

The nomenclature system shown on Fig. 39 is to be followed in both binary and multicomponent equations. It will be noted that the theoretical plates or stages in the enriching section are numbered from the top toward the feed point, the terminal plates being identified by "1" and "n,' at the top and bottom of the section, respectively. Likewise, the plates in the stripping section are numbered from the bottom toward the feed point, the terminal plates being identified by "1'" and "m," at the bottom and top of the section, respectively.

Any plate in the enriching section will be designated as "i" and any plate in the stripping section as "j." This is a change from nomenclature used in Figs. 14 and 15 and equations (8) and (9) of Part 2. In these Part 2 items "i" should be used because they apply to the enriching section. These theoretical plate or equilibrium stage numbers are used as subscripts of L and V to indicate the molal quantities of liquid and vapor leaving the indicated stage. Other terms employed are F, D, and B, identifying the feed, distillate, and bottom streams, with appropriate subscripts for the related L and V streams. Reboiler vapor and reflux liquid are designed as V_b and L_d, respectively. The feed will usually be at or in between the boiling and dew points, in which case it will separate into vapor and liquid fractions in the column. These fractions are in equilibrium and and identified by V_f and L_f.

Capital letters designate total quantities in mols. The amounts of any component are then found by multiplying by the mol fraction, x or y, giving:

$l = xL$, and $v = yV$.

The lower case v and l are used, with the proper subscripts, to identify the concentrations of any component in the vapor or liquid at the particular location in question. Likewise, the small letters, f, d, and b apply to the feed distillate and bottoms product where:

$f = zF$, $d = yD$, and $b = xB$.

In developing the theoretical plate and component distribution equations for fractionation, these lower case terms for component concentration will be used along with the mol fraction and total quantity symbols.

The nomenclature system shown on Fig. 39, and discussed above, will be followed in developing process design methods for binary and multicomponent mixtures. Multicomponent calculation methods may be used for binary mixtures, but not vice versa. The methods developed and discussed below will be limited to two-component systems, where the graphical technique may be employed. The mathematics of these binary graphical methods is a special case of the more comprehensive equations used in making multicomponent calculations.

One of these graphical methods uses an XY diagram, on which are plotted equilibrium and material balance operating lines. This XY diagram method is known as the "McCabe-Thiele" (2) method. The other graphical method uses an enthalpy-concentration diagram, on which there are plotted equilibrium and heat balance operating lines. This HX diagram method is known as the Ponchon (3)-Savarit (4) method.

The application of the XY and HX charts to binary distillation calculations is accomplished by graphical step-wise construction, moving from equilibrium to operating line and back to equilibrium line, etc. These methods were described briefly in Part. 2.

DEVELOPMENT OF XY GRAPHICAL METHOD

In Part 2 the definition of the equilibrium phase distribution constant was given as:

$$K = \frac{y}{x} = \frac{v}{l}\frac{L}{V} \quad . \quad . \quad . \quad . \quad . \quad . \quad (8)$$

from which it follows that:

$$\frac{KV}{L} = \frac{v}{l} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (81)$$

for any component in an equilibrium contact stage. Equations (8) and (81) give two equilibrium relationships that are equally valid for binary and multicomponent systems; however, equation (8) is the one that must be used in these graphical binary calculation methods.

In the McCabe-Thiele method, y, the mol fraction of one of the components in the vapor phase, is plotted against x, the mol fraction of the same component in the liquid. On such a plot, the equilibrium line is the relationship between x and y in the liquid and vapor streams *leaving* any theoretical plate. The operating lines (there are two, one in the enriching and one in the stripping section) give the relationships between x and y in the liquid *leaving* and the vapor *going to* any theoretical plate, thus a component material balance. In this connection, reference is made to Figs. 14 and 15 in Part 2. The location of "any" theoretical plate, for which the equilibrium and operating relationships are given graphically as described and shown, is given in terms of x or y.

With an XY chart of this kind, i.e. with equilibrium line and operating lines constructed for the particular two-components and conditions (pressure and rate of heat addition or removal) in

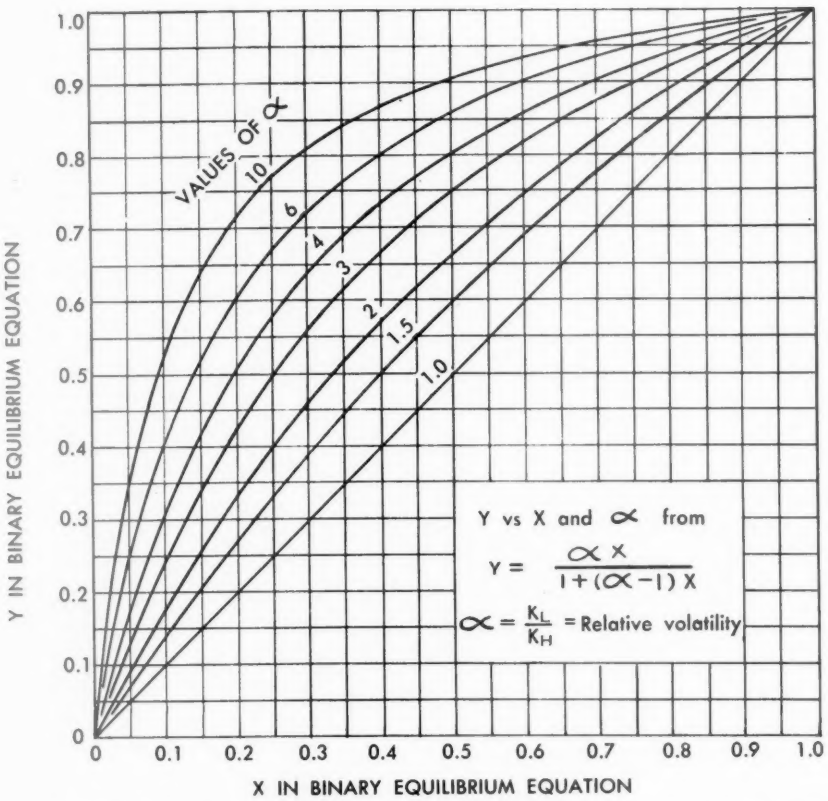

FIG. 40. Equilibrium curves (XY) for binary systems as function of relative volatility or separation factor. X and Y in this figure refer to the more volatile component.

question, graphical step-wise constructions may be made to find the number of equilibrium stages and/or the compositions of the products.

The equilibrium line relationship is a function of the relative volatility of the two components, where relative volatility is ratio of the K constants. In terms of α, the relative volatility, and x and y for the lighter and more volatile component, the equation for the equilibrium line is:

$$y = \frac{\alpha x}{1 + (\alpha - 1)\, x} \quad . \quad . \quad . \quad (82)$$

Equation (82) is another form of equation (5) in Part 2. Fig. 40 is a plot of equation (82) for values of α from 1.0 to 10.

The relative volatility, α, is the ratio of the K constants of two components. If the K for the most volatile is put in the numerator, α is greater than 1.0. When α is greater than 1.0, x and y in equation (82) apply to the most volatile component. When α is less than 1.0, x and y apply to the least volatile component.

For any given α value, equation (82) may be applied to a binary mixture with no attention to temperatures, although each point on an equilibrium curve has a definite temperature for a fixed pressure. Estimating temperature involves calculating the K constant of the least volatile component by the following equation:

$$K = \frac{1}{1 + (\alpha - 1)x} \quad . \quad . \quad . \quad . \quad (83)$$

Where:

K = equilibrium constant of *least* volatile component,

x = mol fraction of *most* volatile component in liquid phase,

α = relative volatility, ratio: K for *most* volatile to K for *least* volatile.

Knowing K from this equation, it is a simple matter to look on a chart and find the temperature for a given point.

Equation 83 follows from equation 82 and the definitions of K and α. Both are equations for the equilibrium line of a binary mixture. When $x = 0$ for the *most* volatile, the equilibrium temperature is the temperature at which $K = 1.0$ for the *least* volatile component. Likewise when $x = 1.0$ for most volatile, the equilibrium temperature is the temperature at which $K = 1/\alpha$ for the *least* volatile component.

In order to illustrate this procedure, Fig. 41 was constructed for binary mixtures having relative volatilities of 2, 3, 5, and 10. This is the temperature—composition type diagram, with temperature expressed as a function of the equilibrium constant of the least volatile component.

The temperature-composition diagrams are not as useful in making binary distillation calculations as the XY diagram and even the XY diagrams have their limitations.

At this point it is of interest to note the similarity between Fig. 40 and Fig. 21 of Part 3. Fig. 21 was constructed from the true boiling point distillation properties of the equilibrium vapor and liquid from flash vaporization for stocks of difference TBP slopes. Fig. 21 applies to a multicomponent mixture. Fig. 40, on the other hand, was constructed from two-component relative volatility data. From these two plots it can be seen that there is a relationship between TPB slope and the relative volatility, α. This will be discussed in more detail in a

FIG. 41. Temperature-composition diagram for binary systems of different relative volatilities, temperature being expressed in terms of K constant of least component.

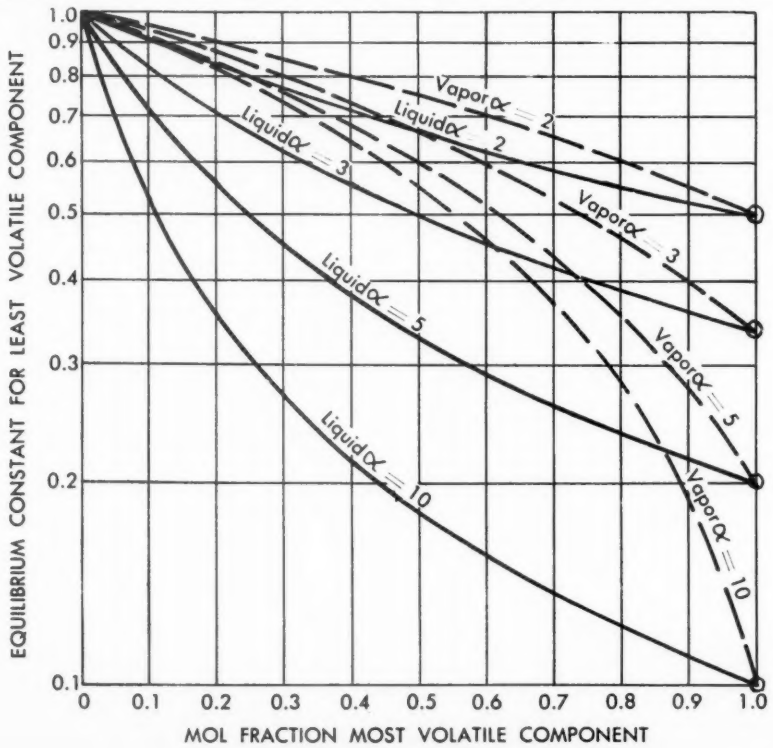
EQUILIBRIUM CONSTANT FOR LEAST VOLATILE COMPONENT
MOL FRACTION MOST VOLATILE COMPONENT
Vapor α = 2
Liquid α = 2
Liquid α = 3
Vapor α = 3
Liquid α = 5
Vapor α = 5
Liquid α = 10
Vapor α = 10

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FIG. 42. Features of the McCabe-Thiele diagram for binary fractionation calculations.

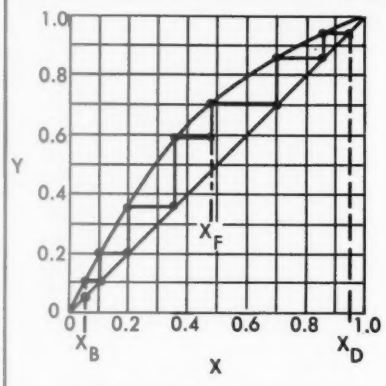

FIG. 42a. Minimum plates and total reflux.

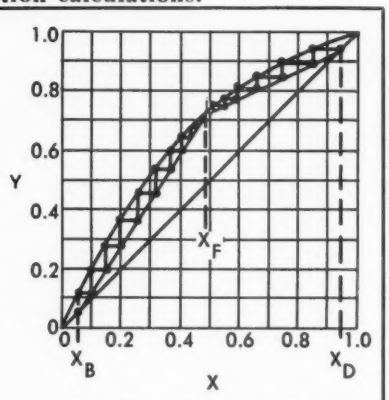

FIG. 42b. Minimum reflux and infinite plates.

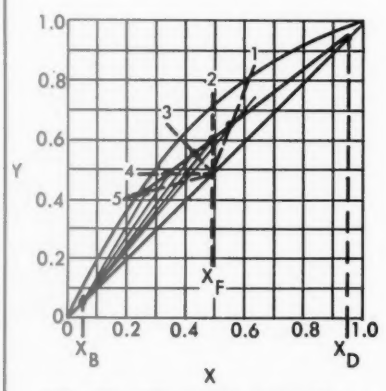

FIG. 42c. Effect of feed condition on operating lines for fixed reflux ratio. (See Fig. 44).

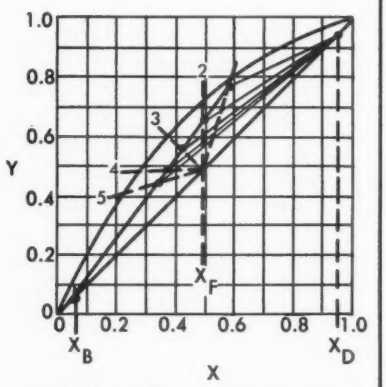

FIG. 42d. Effect of feed condition on operating lines for fixed boil-up ratio. (See Fig. 44).

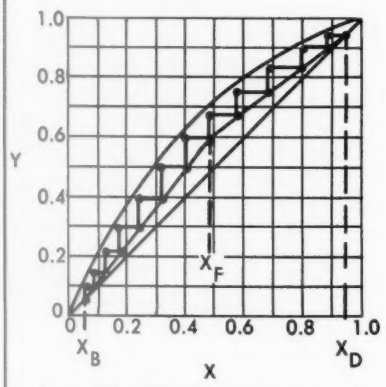

FIG. 42e. Diagram incorporating equilibrium efficiency of plates. (75 per cent in this case).

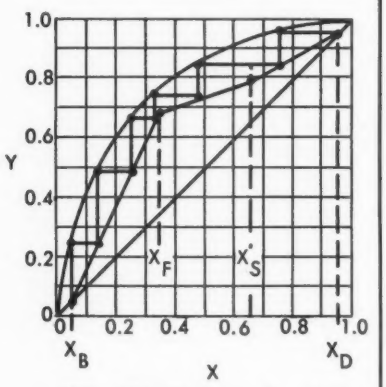

FIG. 42f. Diagram for fractionator with side stream.

later chapter and used as a basis for an empirical method.

The operating lines for the XY diagram graphical method are obtained for the enriching and stripping section by making component material balances for each section. A component material balance is written around any plate "i" in the enriching section and including the reflux condenser and accumulator, giving:

$$y_{i+1} = \frac{L_i}{V_{i+1}} x_i + \frac{d}{V_{i+1}} \quad . \quad . \quad (84)$$

Equation (84) is the equation for the enriching section operating line, the term (L_i/V_{i+1}) being the slope and the term (d/V_{i+1}) being the y intercept at $x = 0$. Equation (84) is the equation of a straight line, the necessary condition for which is constant L and V throughout the enriching section.

If L/V were not constant, the operating line would be curved; however, for most all binary hydrocarbon systems straight operating lines may be used with no sacrifice in accuracy. When the mixture is not an ideal solution and heat of mixing and unmixing must be taken into consideration, the operating line must be curved. Also, heat losses or removal by reflux may curve the operating line.

The equation for the stripping section operating line is obtained by writing a component material balance around any plate "j" in the stripping section and enclosing the reboiler, giving:

$$x_{j+1} = \frac{V_j}{L_{j+1}} y_j + \frac{b}{L_{j+1}} \quad . \quad . \quad (85)$$

The term (V_j/L_{j+1}) is the slope and the term $\frac{b}{L_{j+1}}$ is the x intercept at $y = 0$ for the stripping section operating line. As in the case of the enriching section, L and V are constant in this equation when the stripping section operating line is straight.

Equation 85 may be written:

$$y_j = \frac{L_{j+1}}{V_j} x_{j+1} - \frac{b}{V_j} \quad . \quad . \quad . \quad (86)$$

It can be seen that equations (84) and (86) are the same form but the slopes and intercepts are different. Both equations fit, the form $y = Mx + \beta$ . . (87)

Where:

M = the slope of the operating line,

β = the intercept of the operating line.

Equations (84) and (85) are used to construct the operating lines on an XY diagrams and used in conjunction with the equilibrium line drawn by means of equation (82). The resulting graph is used to determine the number of theoretical plates or the product compositions by graphical steps constructed between the operating lines and the equilibrium line.

These plate-to-plate calculations may be made by an analytical procedure as well as the graphical one usually employed for binary systems. In either case, the same alternate equilibrium and component material balance computations are made at each plate and equations (82), (83), (84) and (85) are used. With the graphical technique it is easier to mesh the enriching and stripping section calculations at the feed plate. Also, with the graphical method, it is possible to tell by rapid visual inspection how to construct the operating lines so as to obtain a practical, if not optimum, design. With the analytical plate-to-plate calculations, more trials are necessary.

This graphical method, which is known as the McCabe-Thiele method, after the authors that published the method in 1925, is a versatile and illustrative process design method. Some features of the method are shown in Fig. 42.

FEATURES OF McCABE-THIELE XY DIAGRAM

The six XY plots on Fig. 42 are for hypothetical mixtures of constant relative volatilities, i.e. no variation in K_L/K_H from top to bottom of column. Figs. 42a, 42b, 42c, 42d, and 42e are all for a binary mixture having an α value of 2.7, whereas Fig. 42f is for a binary mixture having an α value of 6.0.

Minimum plates with total reflux and minimum reflux with infinite plates represent the limits for any fractionation design problem, multicomponent or binary. These limits are represented graphically for binary mixtures in Figs. 42a and b. Note that the equilibrium lines are exactly the same for both plots but

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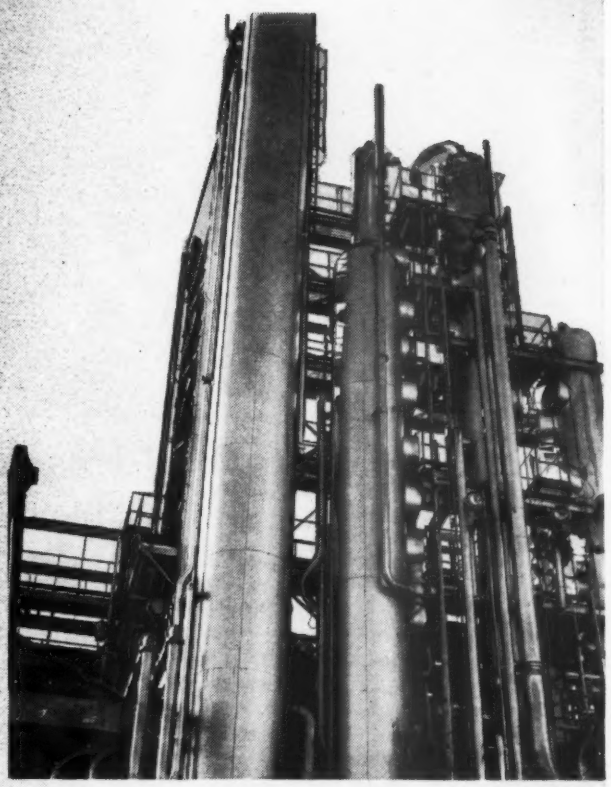

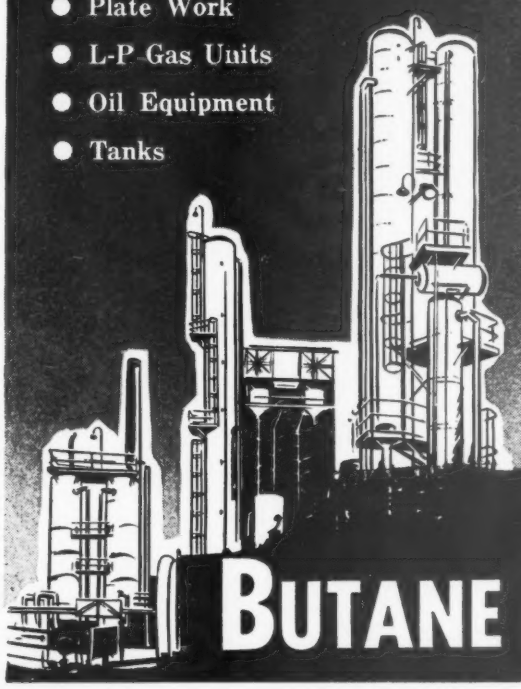

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the operating lines are different. At total reflux no products are removed so the L/V ratios in both enriching and stripping sections are unity in Fig. 42a, and the operating lines coincide with the 45° (or x = y) line. With minimum reflux the operating lines intersect on the equilibrium line, as shown in Fig. 42b.

The number of theoretical or equilibrium stages for these two cases are found by constructing steps between the equilibrium and operating lines as shown, starting from both ends with the products and meshing at the composition of the feed.

In Figs. 42a and b the feed was saturated liquid. There are four other possible phase conditions for the feed, however. These five phase conditions are represented on Figs. 42c and d as, (1) subcooled liquid, (2) saturated liquid, (3) mixed liquid and vapor, (4) saturated vapor, and (5) superheated vapor. The phase condition of the feed affects the relative quantities of reflux in the enriching and stripping sections.

For the diagram shown in Fig. 42c the reflux to the top of the enriching section is held constant for all five feed conditions, thus giving the same L/V ratio in the enriching section, as shown by the single operating line for all cases. The quantities of heat put into the reboiler must be different for the various feed conditions in order to maintain a heat balance. This gives different L/V ratios in the stripping section, as shown by the different operating lines for the different feed conditions.

For the diagram given in Fig. 42d the reboiler heat input is the same for the five different feed conditions, as shown by the single stripping section operating line. Accordingly, the quantities of heat removed by reflux must be different for the various feed conditions in order to maintain a heat balance. This gives different operating lines for different feed conditions.

It will be noted that dashed lines are drawn through the point of intersection of the two operating lines and the feed composition point (on the 45° line) on both Fig. 42c and 42d. The slopes of these connecting dashed lines are determined by the heat balance at the feed zone. In this connection, it is of interest to point out that the construction of the McCabe-Thiele diagram, as illustrated in Fig. 42, assumes that the feed will be introduced at a point corresponding to its composition. Thus, if the composition of the feed is x_f and the feed is saturated liquid, the intersection of the operating lines will be at x_f, where the feed plate liquid will have the same composition as the feed. If, on the other hand, the feed is saturated vapor, the operating line intersection will be at $y = x_f$. Thus, the vapor leaving the plate has the same composition as the feed when the feed is saturated vapor. Other feed conditions are indicated on Figs. 42c and d.

These graphs show clearly the effect of adding heat or supplying cooling via the feed. Vapor feed shortens the stripping section operating line and lengthens the enriching section operating line. When the feed is other than saturated vapor or liquid the slopes of the two operating lines and their intersection point may be found by making heat balances. It is not necessary to develop mathematical equations for the location of the intersection point. It is more convenient to determine the slopes and intercepts for each case directly by heat balance, etc.

With an actual plate equilibrium may not be reached. This is represented on Fig. 42e, where the steps are near but not on the equilibrium line, giving about one-third more plates than theoretical. This corresponds to an overall plate efficiency of 75 per cent. In drawing Fig. 42e, local efficiencies, rather than an overall efficiency, are used. Local efficiency is defined in terms of approach to equilibrium. Efficiencies will be the subject of a later installment.

When an intermediate side stream is removed from the enrichings section of the fractionator, the operating line is drawn in two segments that intersect at the side stream composition (Fig. 42f).

ANALYTICAL METHOD FOR BINARY SYSTEMS

The graphical method of McCabe-Thiele is rather tedious when the operating and equilibrium lines are close together, which requires many small steps. In many cases it is necessary to redraw a portion of the chart to an enlarged scale for these graphical calculations. In addition to being time consuming, these constructions are often not accurate. Of course, plate-to-plate calculations could be made but this would also be tedious.

There are two analytical binary distillation calculation methods of interest, namely: Lewis (1) and Smoker (5). Both of these methods use relative volatility α. The Lewis method employs a differential equation that is integrated from product composition to feed plate composition. The Smoker method is algebraic, using the root of a quadratic to establish constants for the equations.

Lewis (1) proposed a calculation method based on a differential expression of the rate of concentration change in the liquid in going from one plate to the next. For the most volatile component in the enriching section, going toward the feed plate,

$$x_{i+1} = x_i - \frac{dx}{dn} \quad . \quad . \quad . \quad . \quad . \quad . \quad (87)$$

and (from equation 84 by using $V = D + L$)

$$y_i = x_i + \frac{D}{L}(x_D - y_{i+1}) \quad . \quad . \quad (88)$$

In these equations the plates are numbered from the top to the feed. The term dx/dn has a negative sign because the concentration decreases. Combining 87 and 88 and letting x and y denote composition at any point,

$$dn = \frac{dx}{x - y - \frac{D}{L}(x_D - y)} \quad . \quad (89)$$

By equation (82) y may be replaced by terms in x and α. This gives

$$dn = \frac{dx}{\left[\frac{(\alpha-1)x^2+(\alpha-1)x}{1+(\alpha-1)x}\right] - \frac{D}{L}\left[\frac{x_D[1+(\alpha-1)x]-\alpha x}{1+(\alpha-1)x}\right]} \quad . \quad . \quad . \quad . \quad (90)$$

An integration of this equation from x_D (distillate) to x_n (feed plate) will give the number of the theoretical plates. A similar equation may be written for the stripping section.

Smoker (5) developed an analytical equation for the solution of binary fractionation problems. The bases for Smoker's method are: (a) constant reflux ratio and (b) constant relative volatility. The analytical equation is developed by: (a) combining the equilibrium and operating line equations (82 and 84), (b) using the coordinates of the point of intersection of the equilibrium and operating lines, and (c) stepwise manipulation of the algebra to obtain the equation for the number of plates. This algebra is not too complex for two components. The final equation developed by Smoker (5) for the enriching section is

$$n = \frac{\log \dfrac{x'_o\left[1 - \dfrac{MC(\alpha-1)}{\alpha - MC^2}x'_n\right]}{x'_n\left[1 - \dfrac{MC(\alpha-1)}{\alpha - MC^2}x'_o\right]}}{\log \dfrac{\alpha}{MC^2}} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (91)$$

Where:

$$M = \frac{R}{R+1} = \frac{\frac{L}{D}}{\frac{L}{D}+1} = \frac{L}{L+D} = \frac{L}{V}$$

$x'_o = x_D - k$

$x'_n = x_n - k$

$C = 1 + (\alpha - 1)k$

k is the root between 0 and 1 in

$$M(\alpha-1)k^2 + [M + \beta(\alpha-1) - \alpha]k - \beta = 0$$

$$\beta = \frac{x_D}{R+1}$$

x_D = mol fraction of most volatile component in distillate,

x_n = mol fraction of most volatile component in liquid leaving bottom plate in enriching section,

α = relative volatility = $\dfrac{\text{K most volatile}}{\text{K least volatile}}$

For the stripping section, a similar equation may be written. The enriching and stripping equations may be meshed at the feed plate by taking the feed phase condition into account.

These last two methods have not received very wide usage among process engineers because of the complex mathematics. Nevertheless, they have a definite place in a study of fractionation.

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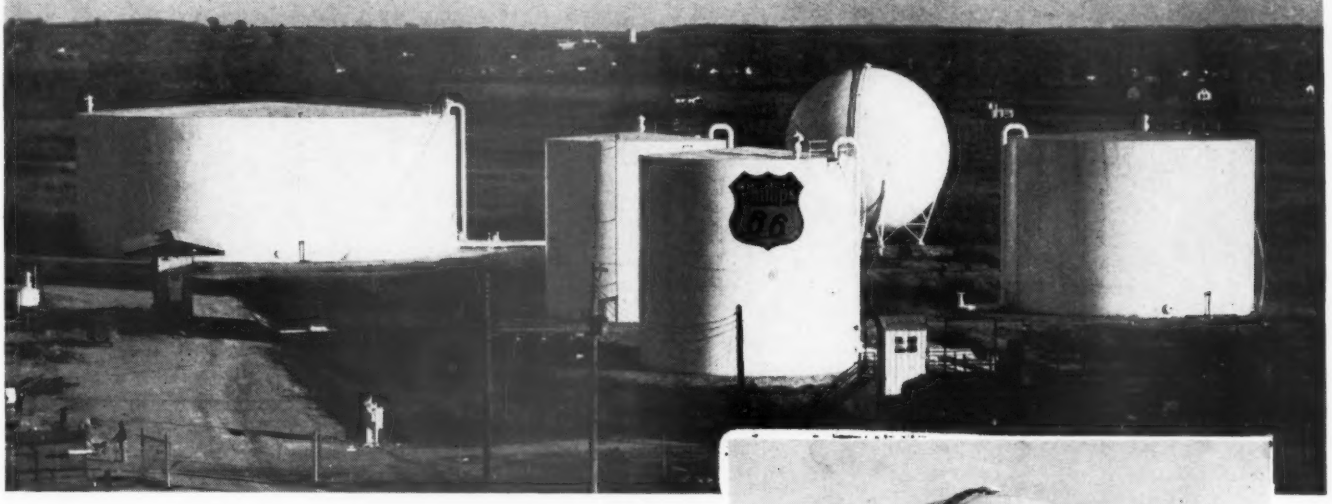
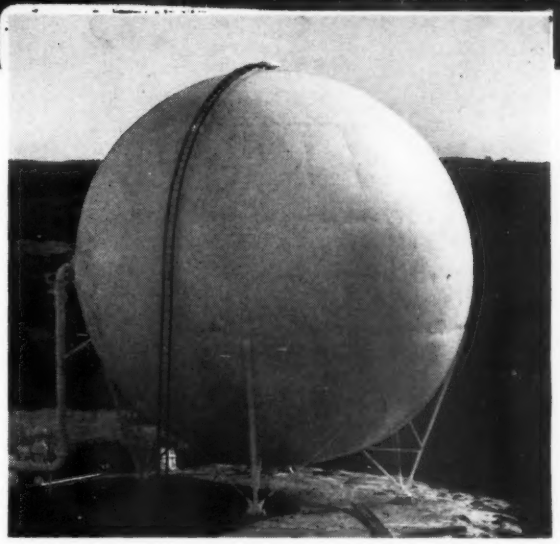
3. Ponchon, *Tech. Moderne 13*, 20 (1921).
4. Savarit, *Arts et Metiers* (1922).
5. Smoker, E. H., *Trans. A.I.Ch.E. 34*, 164 (1938).

★ ★ ★

(Part II will be published soon.)

HORTON VAPORSPHERE REDUCES EVAPORATION LOSSES FROM CONE-ROOF TANKS STORING GASOLINE AND DISTILLATE





THE Phillips Petroleum Company uses a Horton Vaporsphere at its Green Bay, Wis., terminal to reduce evaporation losses. The Vaporsphere is connected to four cone-roof tanks, forming a vapor-saving system.

The Vaporsphere consists of a steel shell with a flexible, hemispherical membrane on the inside. The outer edge of this membrane is connected to the shell at the equator. Large-diameter piping connects the vapor spaces of the tanks to the Vaporsphere. When vapor is displaced from the tanks by breathing or unbalanced filling, it flows into the Vaporsphere. The membrane billows upward and the incoming vapor is stored between the membrane and the lower half of the shell of the Vaporsphere until the conditions which caused its displacement are reversed. It then returns to the tanks. Vapor does not escape from the system under normal operating conditions, hence there are no evaporation losses.

★ ★ ★

The following table shows how the evaporation losses from a Horton Vaporsphere compare with the losses from a cone-roof tank. Calculations based on cone-roof tanks averaging 1/3 full storing 10-lb. Reid vapor pressure gasoline at 56°F.

TANK CAPACITY	EVAPORATION LOSSES IN BARRELS OF 42 U. S. GALLONS			
	GASTIGHT CONE-ROOF TANK		GASTIGHT CONE-ROOF TANK AND VAPORSPHERE	
	Annual Breathing	One Filling	Annual Breathing	One Filling
40,000	960	60	0	48
80,000	1700	120	0	96

The large photo at the top of the page shows how the Phillips Petroleum Company uses a Horton Vaporsphere in conjunction with four cone-roof tanks to reduce evaporation losses at its terminal in Green Bay, Wis. The small photo directly above shows a close-up of the Horton Vaporsphere and the vapor line which connects it to the four cone-roof tanks

Formulae and engineering tables for determining the correct capacity Vaporsphere, the correct diameter of the vapor lines and other necessary data to design a vapor-saving system to meet your particular requirements are found in our new Bulletin D. Write our nearest office for your copy.

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A 6-ft pipelayer extension mounted on tractor helps set six 40-ft joints of pipe in ditch at river crossing near Limon, Colorado. Below, electric welding pipe joints. Three beads were run on each joint. The "stove-pipe" method of lining up the pipe was employed.

New line takes more gas into Denver

EXCLUSIVE Petroleum Engineer Picture Story

By FRANK H. LOVE, *Managing Editor*

The 20-in gas line of Colorado Interstate Gas Company from the Hugoton field, Kansas, to Denver, Colorado, is now in operation. There are 240 miles of 20-in. mainline, which originates at Lakin, Kansas, and a 20-mi, 20-in. loop around Denver. The entire job was completed in 90 working days.

The terrain through which the right-of-way runs offered no problems to the line's construction. From Lakin 142 miles to a point south of Hugo, Colorado, the country is level, and from there into Denver rolling with virtually no rock.

Two spreads were employed for the work. One spread had its headquarters first at Syracuse, Kansas, then moved to Eads, Colorado. The other spread started at Limon, Colorado, and moved to Aurora, a suburb of Denver. Due to the sparsely settled nature of the country, it was necessary to establish camps for the labor with tents providing the shelter.

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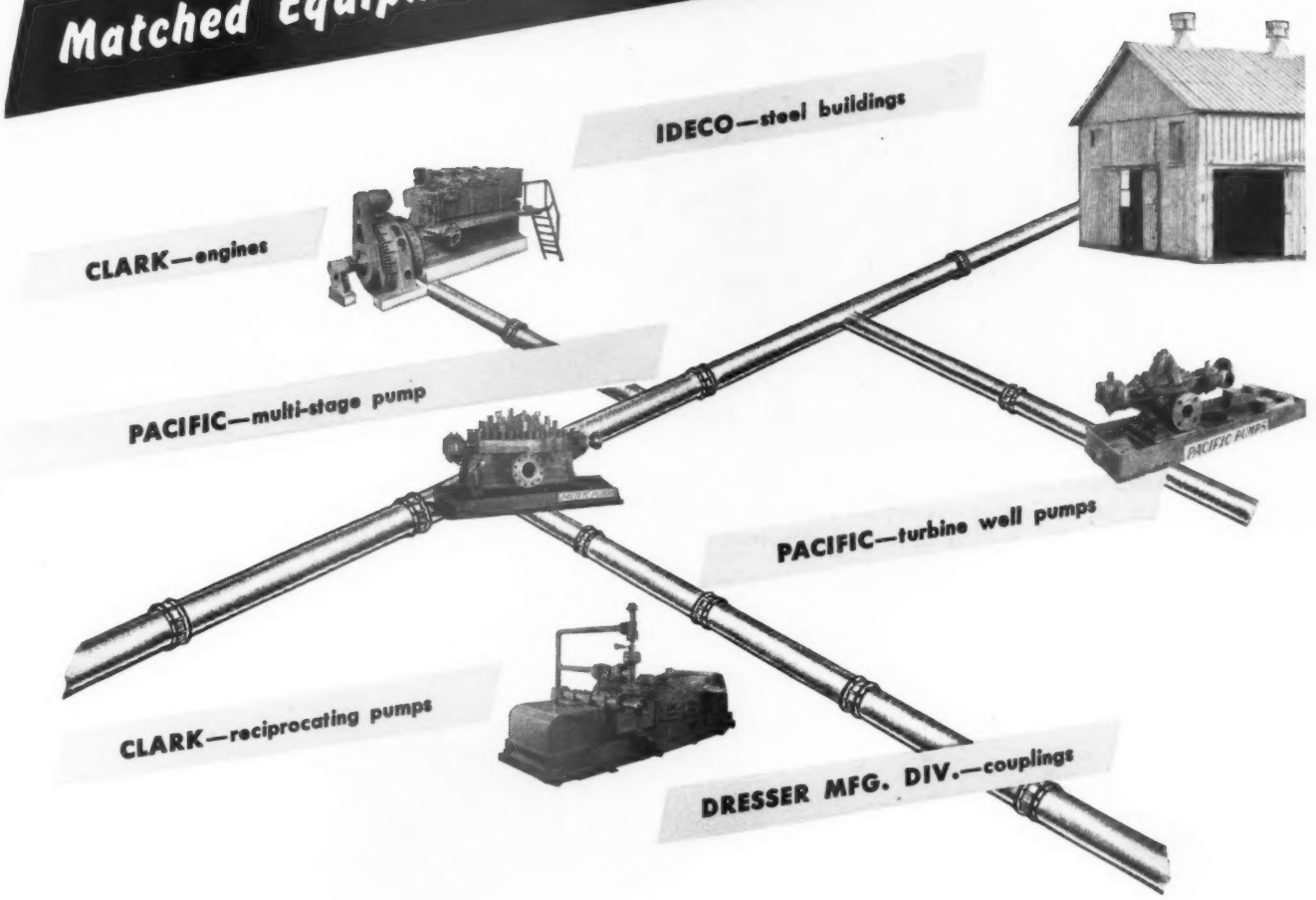

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The line was coated over its entire length with hot enamel. Half of the line was wrapped with asbestos felt, the other half with fiberglas and kraft paper. Coating was applied to a thickness of 3/32 in. New type "dope" kettles, shown at the right in the photograph, were used on the job, three on each spread. Behind the coating machine the holiday detector is being run.

Fifteen stream crossings were made. This one was dry at the time the pipe was laid and a dragline is making the ditch. Pipe was covered 15 to 30 ft for some distance on each side of stream so that if the channel changes the line will not be washed out.

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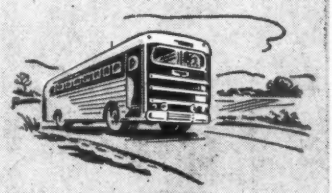

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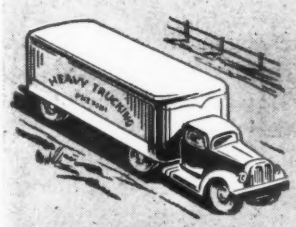

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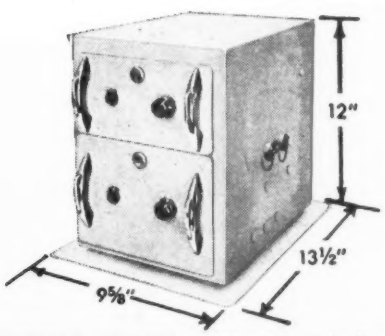

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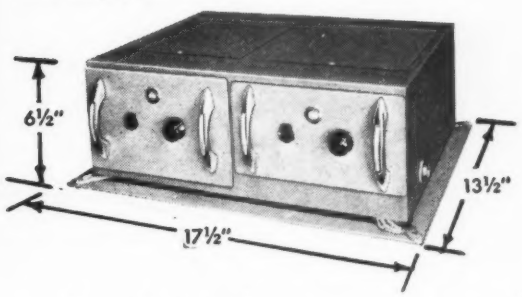

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Laying an approach to a stream crossing. River clamps weighing 1500 lb each were installed every 30 ft. Here tractors equipped with sidebooms are lowering section of pipe into ditch made by dragline. A total of 15 streams was crossed in laying the line.

Crossing an almost dry creek at the time the line was laid, the end of the pipe is skidded-up high awaiting the next tack weld. The line-up clamp can be seen protruding from one end of the pipe and in the background the finishing welders are at work.

A major problem was transportation, the average haul to the line being 25 miles. Fifty automotive units were used by each spread.

The line was laid by J. R. Horrigan Construction Company. Ford, Bacon and Davis, Inc., was the engineering firm in charge of construction and design. A compressor station was built at Lakin by Stearns-Roger Manufacturing Company. ★★★

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Typical Petroleum Industry Problems

Equipment To Be Coated	Characteristics Of Exposures	Coating Recommended
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TUBING CASING DRILL STEM SUCKER RODS (For service in sour crude and salt water.)	Hydrogen sulfide, salt water and sour crude. Paraffin and gyp scale build-up in tubing.	AMERCOAT No. 23 prevents corrosion due to salt water, sour crude, and electrolytic action under gyp scale. AMERCOAT greatly reduces the build-up of paraffin in tubing. Actual records show that AMERCOAT increases the life of well tubing over six times.
RUN-DOWN TANKS GASOLINE STORAGE TANKS	Sweet or sour gasoline and other petroleum products, sulfides, salt or fresh water. Vapor space subject to corrosion from condensation and hydrogen sulfide gas.	Interior—AMERCOAT No. 23 is entirely insoluble in petroleum products and prevents corrosion due to condensation, sour oil and gasoline. Highly resistant to sodium chloride and magnesium chloride brine. Such tanks protected with AMERCOAT have been in service for over four years. Exterior—Three coats AMERCOAT No. 33. Excellent resistance to weathering, salt air and chemical fumes.
CAUSTIC SODA STORAGE TANKS	Interior surface subject to constant immersion in caustic soda solution up to 50% concentration. Exterior surfaces subject to splash and spillage of caustic soda, and weathering.	Interior surfaces—AMERCOAT No. 31 is unaffected by dilute or concentrated caustic soda. Exterior—Three coats AMERCOAT No. 33. Unaffected by caustic soda spillage. Excellent weather resistance.
PERCO SWEETENING SYSTEMS	Severe corrosion caused by copper chloride and gasoline.	Interior—AMERCOAT No. 44 for process tanks. AMERCOAT Plastic Lined Pipe for piping. Exterior of equipment—Three coats AMERCOAT No. 33 in desired color. (14 colors available.)

Free Corrosion Manual

Causes of corrosion and how to prevent it are fully covered in this booklet as indicated by the actual excerpts shown above. Since causes of corrosion vary in different industries, individual manuals have been prepared for each industry.

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New process to make specialized alloy steels

AN important metallurgical development marking a basic advance in the manufacture of specialized alloy steels has been announced by The M. W. Kellogg Company, chemical engineers, in a statement issued by H. R. Austin, president of that company.

The development is based on a new process for making alloy steels, perfected by Kellogg over the last decade.

● **The process.** Technically, the metallurgical process is an electric ingot method for continuous metal casting. Alloying elements are continuously fed at a controlled rate into an electrical apparatus from which air is excluded, and in which an ingot of any desired analysis is produced by progressive solidification.

● **Advantages of the process.**

Uniformity. Accuracy with which alloying elements are metered, combined with the fact that the ingot is progressively solidified in the same container in which the raw materials are melted, provides not only uniformity of chemical analysis but also uniformity of physical properties. The usual transfer of hot metal from ladle to mold that might give rise to nonuniformity of product is eliminated. The uniformity is obtained not only within an individual ingot but also is carried over from ingot to ingot.

Quality of product. As a direct result of this uniformity and the way in which the ingot is formed, the alloy is substantially free of defects. Highly segregated areas in the center of ingots, internal bursts, segregated carbides, and "piping" (industry term for the development of major central cavities in the ingot) are defects the process eliminates.

Ductility. This property of an alloy, which imparts the ability to "give" a certain percentage without failing is highly desired, particularly in high-speed, high-temperature, turbine wheels. Such a wheel, when fabricated of a ductile alloy, has "toughness," the ability to equalize stresses and so to adjust itself to the abnormal conditions without failing. (Note: The center of a turbine wheel is the point of maximum stress and in the most economical use of metal is also the center of the ingot, which normally is its weakest part.) As an example, standard (0.505 in.) test bars taken from the center of a turbine wheel fabricated of a high temperature alloy made by the Kellogg method exhibited an elongation of more than 20 per cent.

Cost. This process brings alloys having superior characteristics within the price range of ordinary alloys.

Size of ingots. The new process is literally a continuous casting method. There is no limit to the length of ingot it is capable of producing. The ingots now made are between 6 in. and 6 ft.

Flexibility. Small research heats of 25 to 50 lb are produced quickly and without any special conditions in the same equipment used for volume commercial production. This permits quick delivery of small orders and eliminates the uncertainty involved in translating experimental data obtained on small induction furnaces to full-scale operations.

High temperature resistance. It is well known that the efficiency of a heat engine increases with advancing temperatures. Designers of turbo-jet engines for supersonic aircraft have been limited in their application of theory by the physical limitations of the alloys themselves, which, so far, have been able commercially to withstand temperatures up to the 1200 F range, although experimental models have operated at 1450 F.

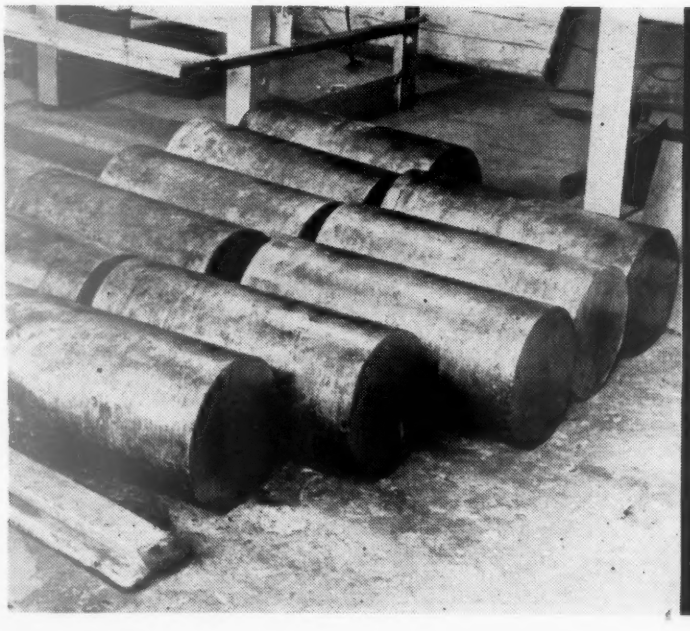
● **Applications of the process.**

1. Turbine wheels for turbo-jet aircraft engines and many other high temperature applications.
2. High speed tool steels. During the war, hundreds of tons of high speed tool steels were successfully made by this process. Tools were used in both the cast and rolled conditions. The tools made directly from the cast metal functioned as well as forged tools of same analysis.
3. Stainless steel alloys of all types, especially where free machining is a desired quality. Kellogg alloys in this classification show definite improvement in machinability.

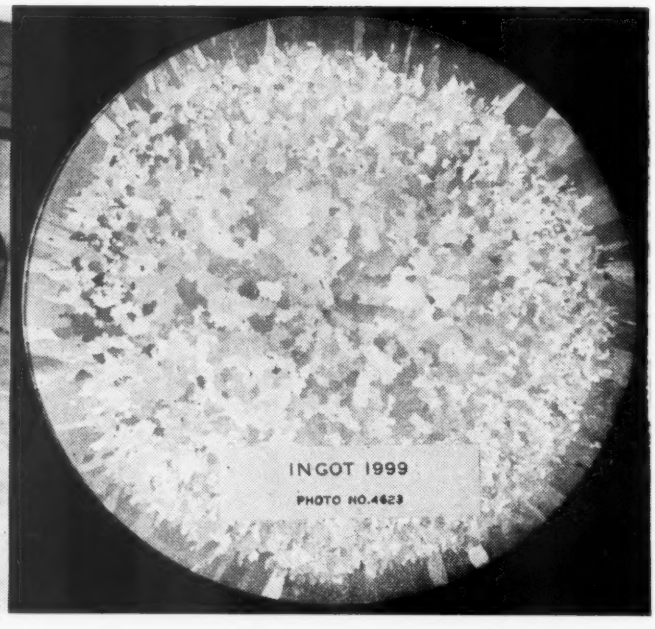
● **History of process.** Research on this new method for producing alloys was begun by The M. W. Kellogg Company 12 years ago. The present method was developed sufficiently during the war to turn out hundreds of tons of specialized alloys for the manufacture of high-speed tools and also a considerable tonnage of stainless steel that went into welding rods for welding armor plate on tanks.

Continuing development has perfected the process with the single ingot production machine being operated at top capacity. To satisfy the orders already received from leading manufacturers all over the country a multiple ingot production is being built at the Kellogg Jersey City plant and will be in operation early in 1948. ★★★

Cast billets 9 in. in diameter and 21 in. long.



Macrograph of a cut from top end of billet.



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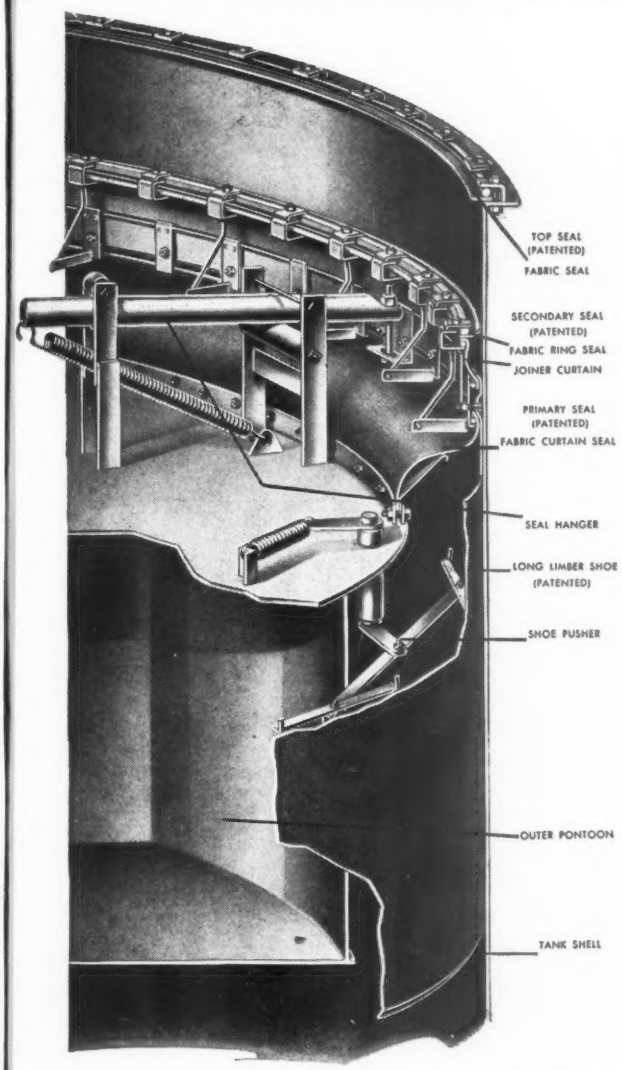

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THE TOP SEAL prevents vapor losses when the float is within three feet of the tank top, at which point the Secondary Seal no longer functions.

For more complete information on how this Triple Seal Protection, plus many other exclusive Wiggins design features reduce evaporation and pumping losses, write for a copy of the Wiggins Hidek Floating Roof Bulletin.

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FIG. 1. Gas and water boils up in a crater around well No. 14 twelve days after high pressure gas escaped into shallow water sands through well No. 101, about 1000 ft south (extreme left). Larger derrick at left is drilling a well to relieve pressure in water sand.

How high pressure gas blowouts in a Texas field were brought under control

By K. MARSHALL FAGIN, *Field Editor*

ALTHOUGH much has been written about techniques and equipment for preventing blowouts during the drilling and production of high pressure oil and gas wells, less has been written about the methods used to combat blowouts that result unexpectedly and accidentally from sudden changes in subsurface conditions as wells are drilled into high pressure gas zones.

EXCLUSIVE

The chief reason for fewer articles about blowouts is simply that drilling and mud control techniques and equipment have been improved so much in the last 20 years that operators have fewer blowouts. High pressure gas sands in the Gulf Coast area provide one of the best proving grounds for modern blowout prevention technique, and operators who drill hundreds of deep wells in these areas can consider themselves particulary fortunate, if none of their wells blowout when the drills penetrate an abnormally high pressure gas sand.

This article concerns the measures used by Magnolia Petroleum Company in combating a series of blowouts that occurred around some of its wells in the Seeligson field of Jim Wells County, Texas, when high pressure gas from a 6200-ft sand blew out in a drilling well and channeled into a shallow water sand.

Seeligson No. 101 was begun on July 2, 1947, as a regular well on the northwest flank of this multiple reservoir field. At a depth of 1039 ft, 10¾-in. surface pipe was set and cemented with 650 sacks of cement. The well was drilled through the normal sequence of shales and sands, and had reached a depth of 6057 ft at 4 p.m. on July 21. Drilling mud weight was being kept at 11 lb per gal, and Marsh funnel viscosity was 43 sec.

Sticky shale and sand streaks were drilled from 6057 to 6139 ft by midnight.

A 9 p.m. check indicated the mud weighed 11 lb per gal and had a viscosity of 45 sec. The well was drilled through shale and sand from 6139 ft to 6204 ft after midnight on the morning

FIG. 2. Gas, water, and mud blow wildly toward the sky from the crater around well No. 14 as gas flows through shallow water sand from well No. 101.

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of July 22. The sand was from 6193 to 6204 ft.

The well began to kick as a connection was being made at 4 a.m. Mud and gas began to blow out above the rotary table, and the blowout preventer rams were closed within 3 min. Mud was then pumped into the drill pipe as the pipe was worked to prevent sticking. The pipe finally stuck, however, at 6125 ft at 8 a.m. More mud was mixed and about 200 bbl was pumped into the drill pipe about 10 a.m. No pressure was indicated on the drill pipe, although the new mud weight was 10.5 lb per gal.

A new mud pit with a capacity of about 700 bbl was dug as mud mixing was continued. The pressure on the bradenhead after the blowout preventer was closed built up rapidly to 500 psig and remained there while mud was being mixed and pumped into the drill pipe. Some gas was bled off the casinghead and the pressure dropped to as little as 125 psig, but returned to 500 psig when the valve was closed.

Water and sand began flowing out around Seeligson No. 14 (see map) about 4 p.m. of the same day. Part of the flow was around the outside of the 13⅜-in. surface pipe, which had been set and cemented at 2047 ft, and part flowed out of the ground about 20 ft southeast of the casing. The water carried out a large quantity of sand before dry gas broke through.

An oil well cementing service truck was called, and the flow lines of No. 14 were equipped for connection with the cementing truck. The lines were torn loose, and No. 14, a zone 14-B completion, was flowing wild from both the casinghead and tubing before the truck arrived.

About 700 bbl of new mud was pumped into No. 101 at 6 p.m., but the bradenhead pressure remained about 500 psig.

Seeligson well No. 16 began to flow water and sand around its 10¾-in. surface casing, which had been set and cemented at 2188 ft, about midnight. This well is about 2550 ft south of No. 101. This well was killed early the next day by using a cementing truck to pump it full of mud weighing 13 lb per gal.

Seeligson No. 13, about 3850 ft south of No. 101, began flowing water around its surface casing at 5 a.m. on July 23. It was killed promptly with 13-lb mud in the same manner as No. 16.

About 300 bbl of 17-lb mud was mixed and pumped into the drill pipe in No. 101 on July 23. A cementing plug was inserted and more mud was pumped into the drill pipe. As the pipe was still stuck, it was decided to shoot it in two. A dummy plug was run with a wire line measuring unit to 4500 ft, where it stopped. A shot was then run. It stopped at 4327 ft, where it was detonated. The sinker bars stuck near the shot point, but the wire line was finally cut off near bottom the next morning.

Well No. 14 blew wild most of the day, July 23, but a flow line was connected successfully to the tubing of this well about dark, and 280 bbl of 11-lb mud was pumped into it. Due to dark-

FIG. 3. South-North cross-section showing the logs of wells on each side of well No. 101. The inset map shows location of wells in this part of the Seeligson field.

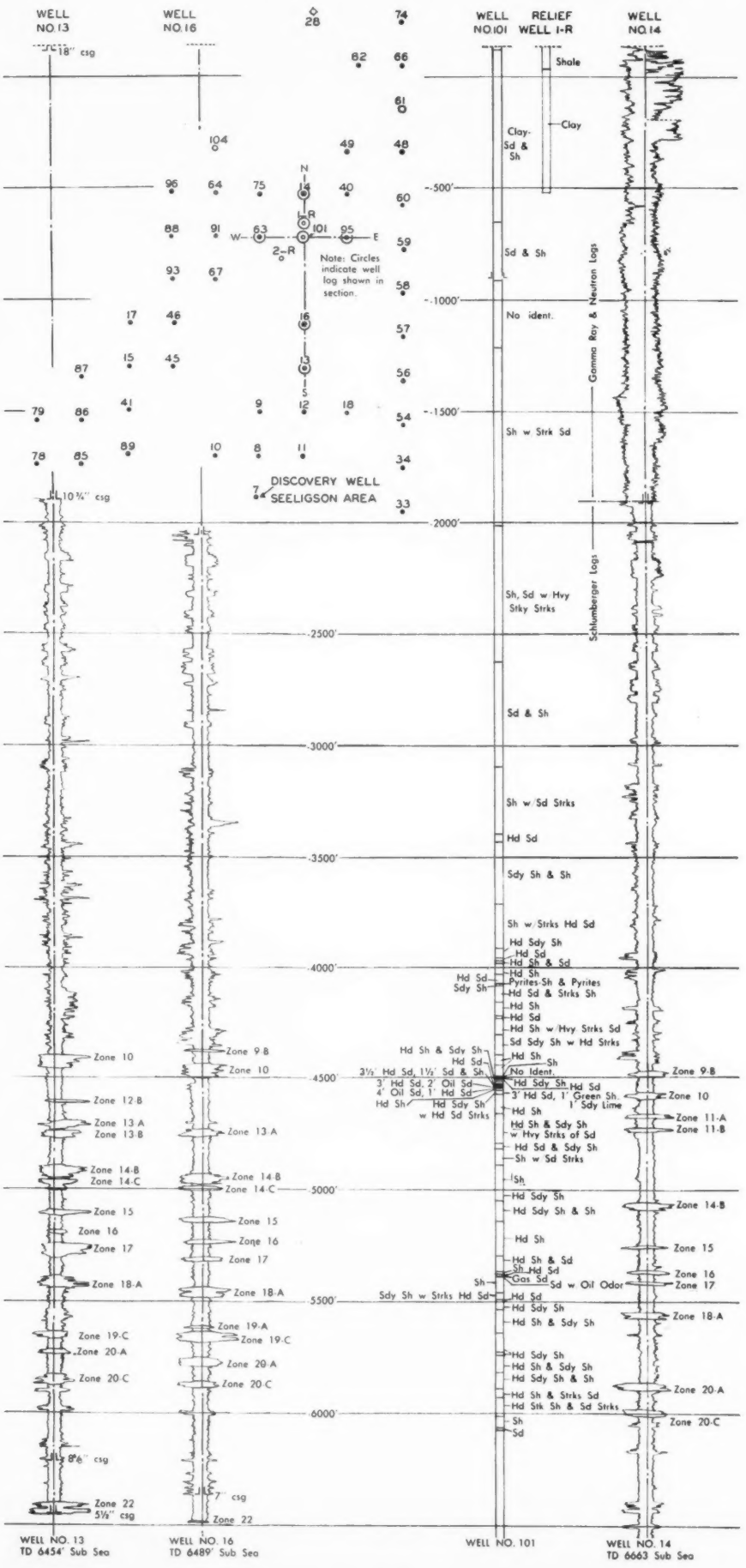

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FIG. 4. The relief well, No. 1-R, is shown as it was being drilled north of well No. 101 (at left).

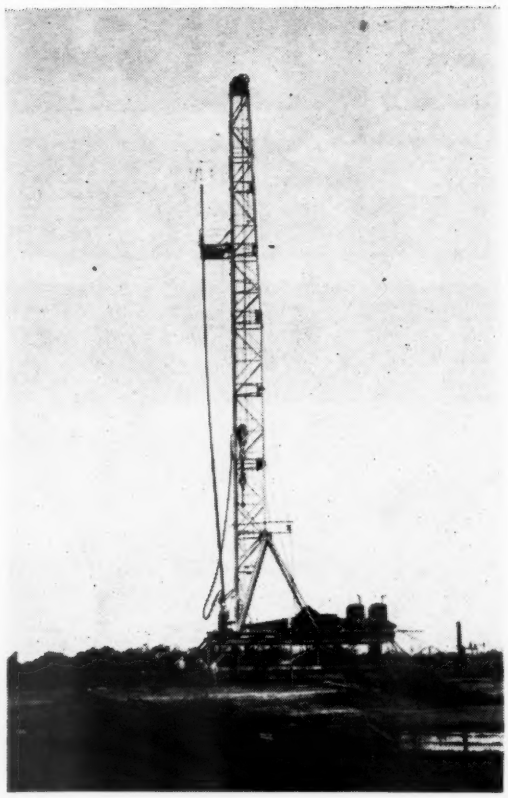

FIG. 5—A portable drilling rig was moved in and rigged up quickly to drill a relief well to the surcharged shallow water sands (at right).

ness and violent eruptions around the well, it was impossible to tell whether or not it had been killed. Pumping was discontinued, however, and the christmas tree was anchored down with cables.

The next day, July 24, more mud was pumped into No. 14. The new mud weighed 17 lb per gal, and returns were soon obtained through the casing connections. Zone 14-B was shut off definitely, therefore, and the well was not producing any more gas and oil into the crater around the surface pipe.

A temperature survey was run on well No. 101 about 6 a.m. the next day, July 25, with a vacuum on the drill pipe. A second temperature survey was run at 1 p.m. with 600 psig on the drill pipe. By the time the second survey ended, the pressure had increased to 1200 psig on the drill pipe, although the bradenhead pressure remained between 450 and 500 psig.

About 1500 bbl of 10.5-lb mud containing lost returns material and cottonseed hulls, and 17,000 sacks of neat cement were pumped into the drill pipe of No. 101. More than 50,000 lb of cottonseed hulls were used. Well No. 14 died down after each batch was pumped into No. 101. After all the mud and cement was pumped into No. 101, the fluid level in the crater around No. 14 dropped about 60 ft, and No. 14 was quiet for about 1½ hr.

Another temperature survey was made in No. 101 against 1200 psig pressure at 6 a.m. the next day, July 26. At noon on that day, No. 14 died down for a brief period. New mud was pumped into No. 14, and a temperature survey run about 2 p.m., but it was impossible to reach bottom on the first run as the well began to blow wilder in the crater around the casing.

Additional mud was mixed in the next day, July 27, for use in No. 101, and 4-in. lines were laid to a point about 300 ft away to relieve the pressure on the well. The pressure on the drill pipe was 310 psig when the well was first opened into the 4-in. relief lines. The well produced at the rate of about 32,000,000 cu ft of gas per day and the pressure on the drill pipe was 325 psig at the end of 12 hr. The bradenhead pressure remained about 500 psig.

The rate of production from No. 101 had increased to 37,000,000 cu ft per day through the two 4-in. lines on the morning of July 28, but the pressure on the drill pipe decreased gradually to 100 psig.

The relief lines were closed in on the afternoon of July 29, and the well was killed by pumping mud into the drill pipe. An impression block was run into the drill pipe on a wire line, and preparations made to dig a larger pit and erect additional boilers and mud pumps.

Water ceased coming up around the casing on well No. 13 and well No. 16 calmed down considerably by the morning of July 30. Junk was fished out of the drill pipe in No. 101, and preparations were made to kill well No. 61, a gas well about 4850 ft northeast of No. 101.

A relief well was rigged up north of No. 101 on July 31, and preparations were made to run a string of special 2-in. tubing into the drill pipe in No. 101. The drill pipe pressure was 1200 psig, and the bradenhead pressure was 450 psig. Wells No. 13 and 16 had ceased blowing out around the surface pipe. On August 1 the 2-in. tubing was run into No. 101 to a depth of 4321 ft. A mill on the tubing became plugged, and preparations were made to pull it. About 4000 bbl of mud was mixed in a large pit near No. 101, and preparations were made to run 80 ft of 20-in. conductor pipe in the relief well, which was spudding in.

The conductor pipe was run and cemented in the relief well on August 2.

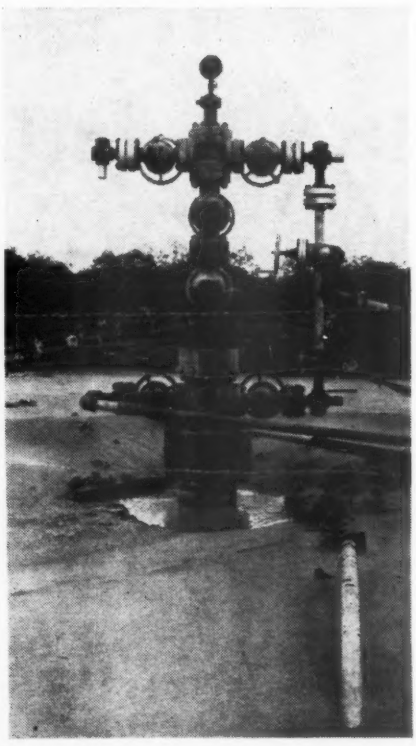

FIG. 12. Well No. 16, about 1300 ft south of well No. 101, did not crater as well No. 14 did but gas, water, and sand boiled up around surface casing.

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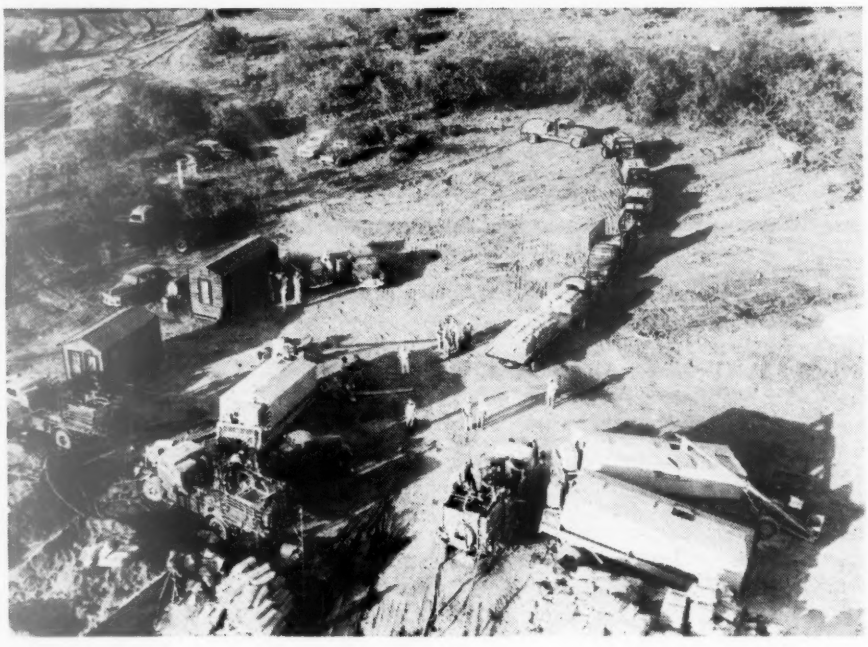
FIG. 6. Thousands of sacks of drilling mud materials and cement were moved to an area near No. 101 to combat escape of high pressure gas to shallow water sands.

FIG. 7. Portable buildings, cementing service trucks, and supplies were moved hurriedly to the scene. Trucks shown are preparing to unload needed materials.



The 2-in. tubing was pulled out of No. 101, and lines were connected to pump more mud and cement into the drill pipe in this well.

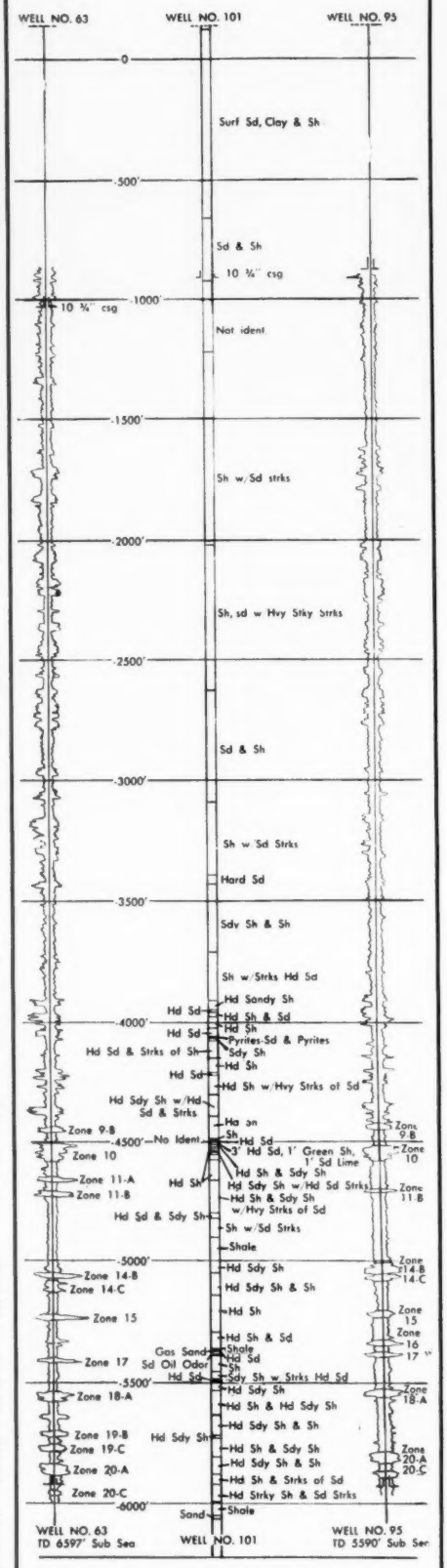
At 11:20 a.m. on August 3, the pumps were started and 1217 bbl of 17-lb mud was delivered into the drill pipe by 2:15 p.m. Well No. 14 quieted down as this mud was injected, and it ceased to blow when the pumps were stopped.

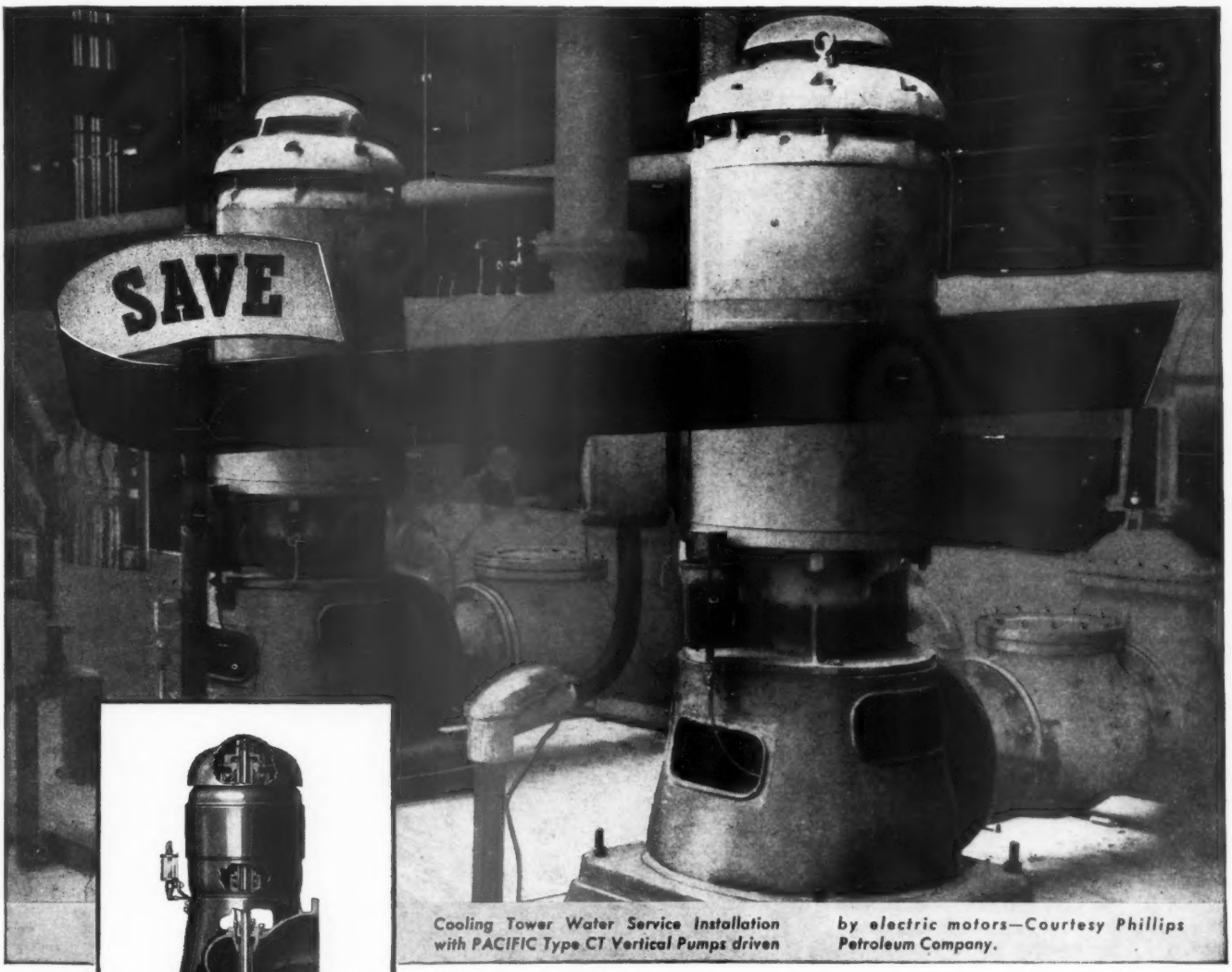
Cement and plugging materials were pumped into No. 101 in six stages beginning immediately after the 17-lb mud was injected. The first batch of materials was pumped into the well from 2:15 p.m. to 2:46 p.m. It consisted of 100 sacks of anhydrous calcium sulphate. This was followed by 750 sacks of cement containing 2 per cent calcium chloride and cellophane strips and mica flakes. This was followed by 65 bbl of 17-lb mud.

The second batch of materials was pumped into the well from 3:33 p.m. to 4:10 p.m. It consisted of 70 bbl of 17-lb mud, 5 bbl of water, 100 sacks of anhydrous calcium sulphate, 750 sacks of cement containing calcium chloride, and 70 bbl of 17-lb mud.

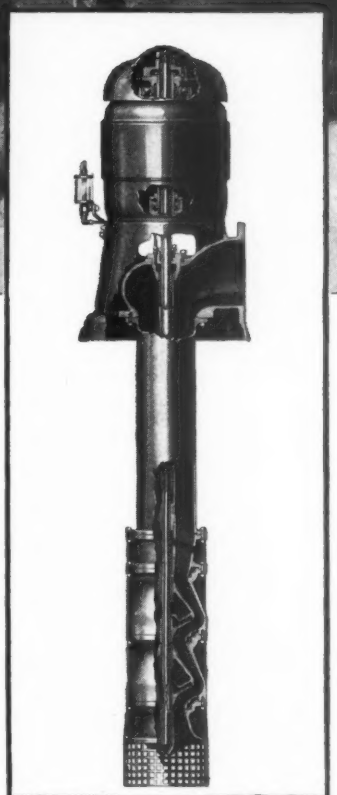
The third stage was pumped into the well from 5:00 to 5:35. The materials and the order of pumping were as follows: 70 bbl of 17-lb mud, 5 bbl of water, 100 sacks of anhydrous calcium sulphate, 750 sacks of cement containing calcium chloride, and 70 bbl, 17-lb mud.

FIG. 8. A west-east cross-section showing the logs of well No. 101 and the offset wells.





Cooling Tower Water Service Installation with PACIFIC Type CT Vertical Pumps driven by electric motors—Courtesy Phillips Petroleum Company.



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The fourth stage was pumped into the well from 6:45 p.m. to 7:21 p.m. The materials pumped and the order of pumping were the same as for stage three. The fifth stage was pumped into the well from 8:45 p.m. to 9:27 p.m. It was likewise the same as stage three, except that 65 bbl of water instead of mud followed the cement. Pressure on the drill pipe during most of the operation was about 1200 psi. The pressure increased to 1500 psi, however, as the water was pumped away, but it decreased gradually while waiting to begin the sixth stage.

The sixth and final stage was pumped into the well from 11:35 p.m. to 11:59 p.m. It consisted of 800 sacks of neat cement and was followed by 65 bbl of water. Pressure on the drill pipe in the well decreased gradually to 900 psi.

Three temperature surveys were made in well No. 101 from 3:30 a.m. to 10:00 a.m. on August 4. The drill pipe was then perforated at 4025 ft with two shots, and 150 sacks of cement were squeezed out of the pipe. The cement broke through at 1200 psi, and the maximum pressure used on the squeeze was 2400 psi.

Well No. 14 remained quiet on August 4, and the fluid level dropped a few feet. The well made a slight blow the next day, but the fluid level in the crater continued to drop. Well No. 101 remained closed in while waiting on cement to set after the squeeze at 4025 ft.

The relief well began blowing gas and water through a 6-in. flow line on August 5 when it reached a total depth of 705 ft. The flow had deceased about 25 per cent the next day, and had almost ceased producing gas by August 7. It continued flowing some water, however, until August 11, when it began again to produce a large volume of gas. The flow subsided gradually until August 14 when it increased suddenly again for the last time. After that, the flow from the relief well subsided gradually until August 27 when it was almost dead and daily reports from the field were discontinued.

In the meantime the fluid level in the crater around well No. 14 continued to drop, the casing was straightened up, and the crater was filled in by bulldozers.

Relief well No. 2-B (see insert map) began drilling on August 10; 8⅝-in. casing was set and cemented in this well at 390 ft with 130 sacks of anhydrous calcium sulphate on August 13. This well was drilled through a sand from 680 ft to 720 ft on August 17, however, it did not show gas. Several other sands were likewise penetrated without any gas shows. The well was abandoned as a possible relief well at 1526 ft on August 26 and was completed as a water well. An effort was made in the meantime to recover as much as possible of the 4½-in. drill pipe in well No. 101. A string of 2⅜-in. drill pipe was run inside of the 4½-in. to 3800 ft on August 7. It twisted off while drilling cement at 3891 ft. The twist off occurred at 1568 ft. The top of the 2⅜-in. drill pipe fish was finally caught hold of by using a skirt on a tapered tap, but the fish could not be pulled as it was stuck near the bottom at 3891 ft.

About 1000 ft of the 4½-in. drill pipe was cut and pulled on August 14, and 7-in. pipe was washed over the top of the 4½-in. fish at 1040 ft on August 15. Returns were lost and 250 sacks of cement failed to obtain a shutoff on August 18. Another cement job on August 19 held, however, and 180 ft more of 4½-in. drill pipe was recovered on August 21. The well was abandoned finally on August 27. ★ ★ ★

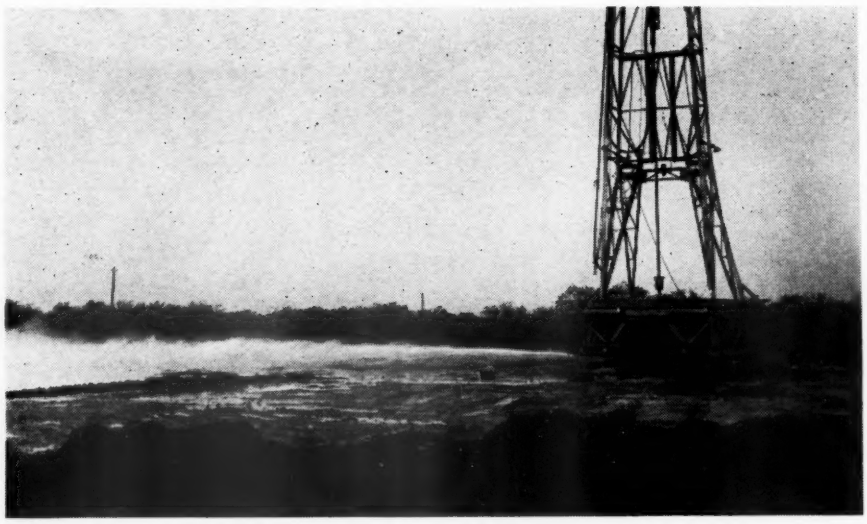


FIG. 9. High pressure gas and water from the shallow water sand was permitted to escape through a 6-in. outlet from relief well No. 1-R.

FIG. 10. A large supply of drilling mud was mixed and conditioned continuously in enlarged pits near well No. 101 during mudding and cementing operations. Mud guns shown are being used to stir the mud in one pit.

FIG. 11. The christmas tree and casinghead of well No. 14 were straightened up by the cables after the blowout subsided, and the crater was filled in by bulldozers.

FIG. 1. Sealing "in vacuum" hydrocarbon standard samples in glass ampoules at the National Bureau of Standards. One hundred and nineteen different standard samples of the highest purity hydrocarbons have been made available to industry for spectrometric calibration through cooperation of the Bureau and the API.

Standard samples of hydrocarbons

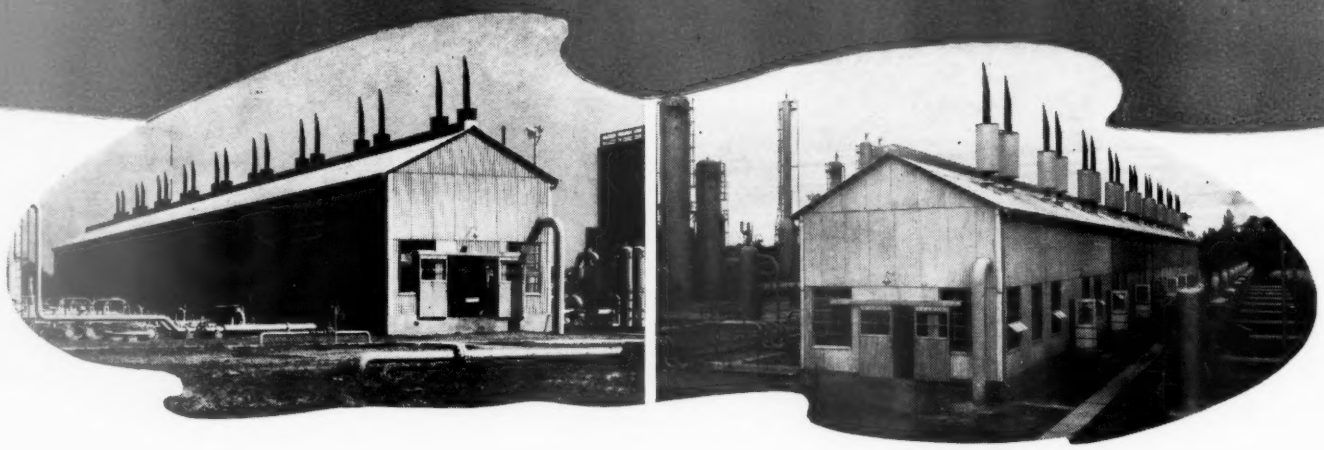
DURING the war the urgent need for hydrocarbons of high purity for the calibration of spectrometers—used by industry in the analysis of mixtures of hydrocarbons involved in the production of military aviation fuel, synthetic rubber, and ordnance components—prompted the Petroleum Industry War Council to request the National Bureau of Standards to include high purity hydrocarbons in its standard sample program. The Bureau's work on standard hydrocarbon samples was initiated early in 1943 and within a year 15 hydrocarbon standards had been completed and offered to industry.

The requirements for new hydrocarbon standards were mounting so rapidly, however, that a much greater rate of production was necessary. Accordingly, the Petroleum Industry War Council requested the American Petroleum Institute Advisory Committee on Fundamental Research on the Composition and Properties of Petroleum to effect a cooperative program with the National Bureau of Standards, whereby all the facilities of the existing research projects of the Institute could be brought to bear on the problem so that the preparation of finished hydrocarbon standards could be materially speeded up. The cooperative program formally began functioning on July 1, 1944, under the newly formed API Committee on Hydrocarbons for Spectrometer Calibration, W. J. Sweeney, chairman.

The American Petroleum Institute Hydrocarbon Research Project (now the American Petroleum Institute Project 45, C. E. Boord, director) at the Ohio State University gave the enlarged program impetus by contributing a large number of hydrocarbons that were on hand as the result of the synthesis of new compounds for the program. The Hydrocarbon Laboratory and the API Research Project 42 at the Pennsylvania State College (F. C. Whitmore, director), which had laboratory facilities and experienced investigators, began the synthesis of new hydrocarbons of the gasoline range. Contributions of material were made by the National Advisory Committee for Aeronautics (through its laboratory at Cleveland and its associated work in the Automotive Section at the National Bureau of Standards), General Motors Corporation, the API Research Project 6, and other laboratories. At the National Bureau of Standards, the API Research Project 6 accomplished the final purifications and determinations of purity, and the Hydrocarbon Standard Samples Laboratory of the Bureau performed the sealing, certification, and packaging.

At the end of two years, during which 75 new hydrocarbon standards had been completed, the API Committee on Hydrocarbons for Spectrometer Calibration was formally disbanded, leaving the

"TWIN" CYCLING PLANTS S



California Company Employs CLARK Compressors in Two New Conservation Projects

Two new cycling plants operated by the California Company, one at Lake St. John, La., and the other at Cranfield, Miss., are "identical twins", although entirely independent in operation.

In each plant, 9 Clark 800 B.H.P. Right Angle Compressors pump dry gas back into the sands at 4,000 pounds pressure per square inch. It is estimated that these two conservation projects will effect a combined saving of 45,000,000 barrels of crude oil and condensate which these fields would otherwise have lost.

Each plant was developed under a voluntary unitization plan, by which each operator and royalty owner receives a percentage of the revenue from the entire field proportionate to his recoverable reserves.

Write for further information on this modern method of increasing yield which has been described as "just like discovering a new oilfield".

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SETS THE PACE IN COMPRESSOR PROGRESS

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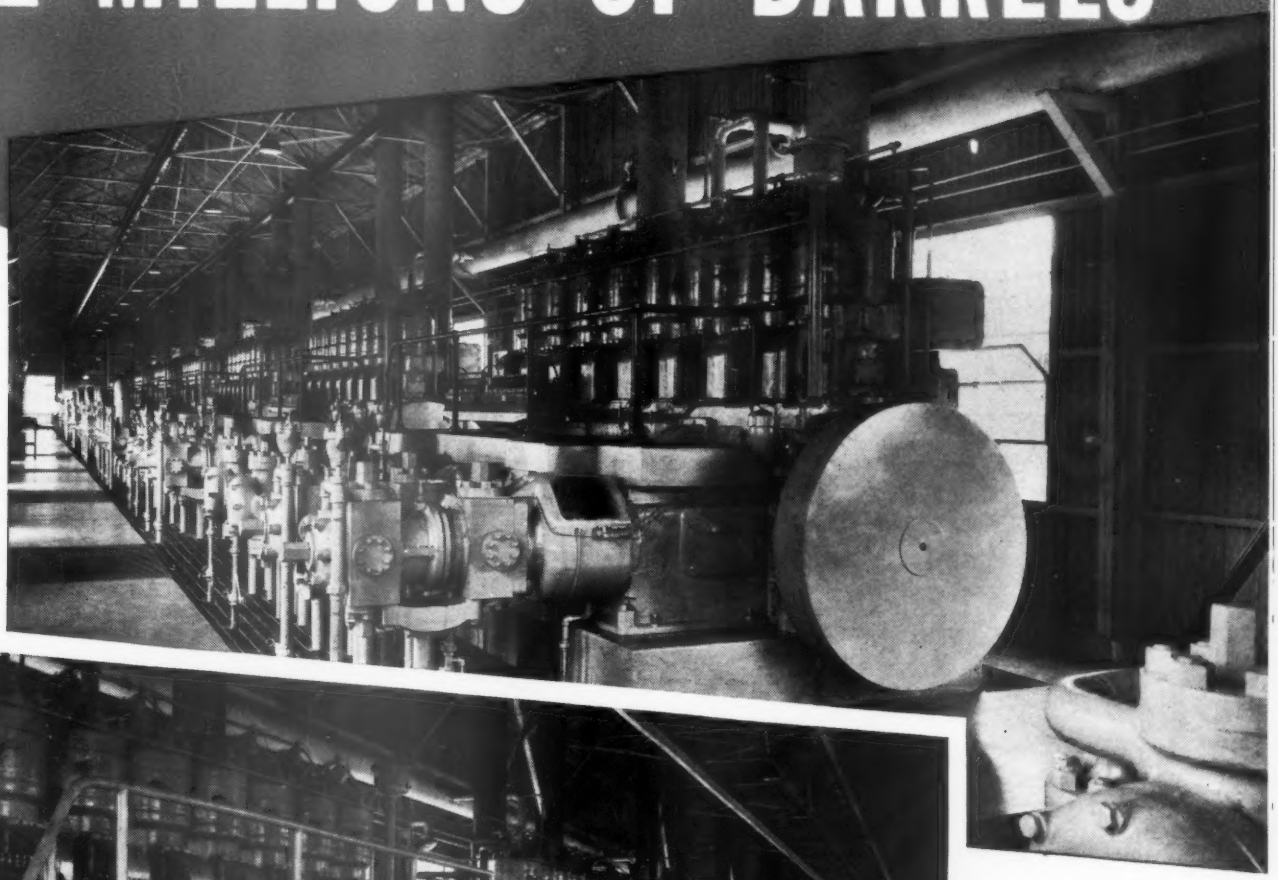

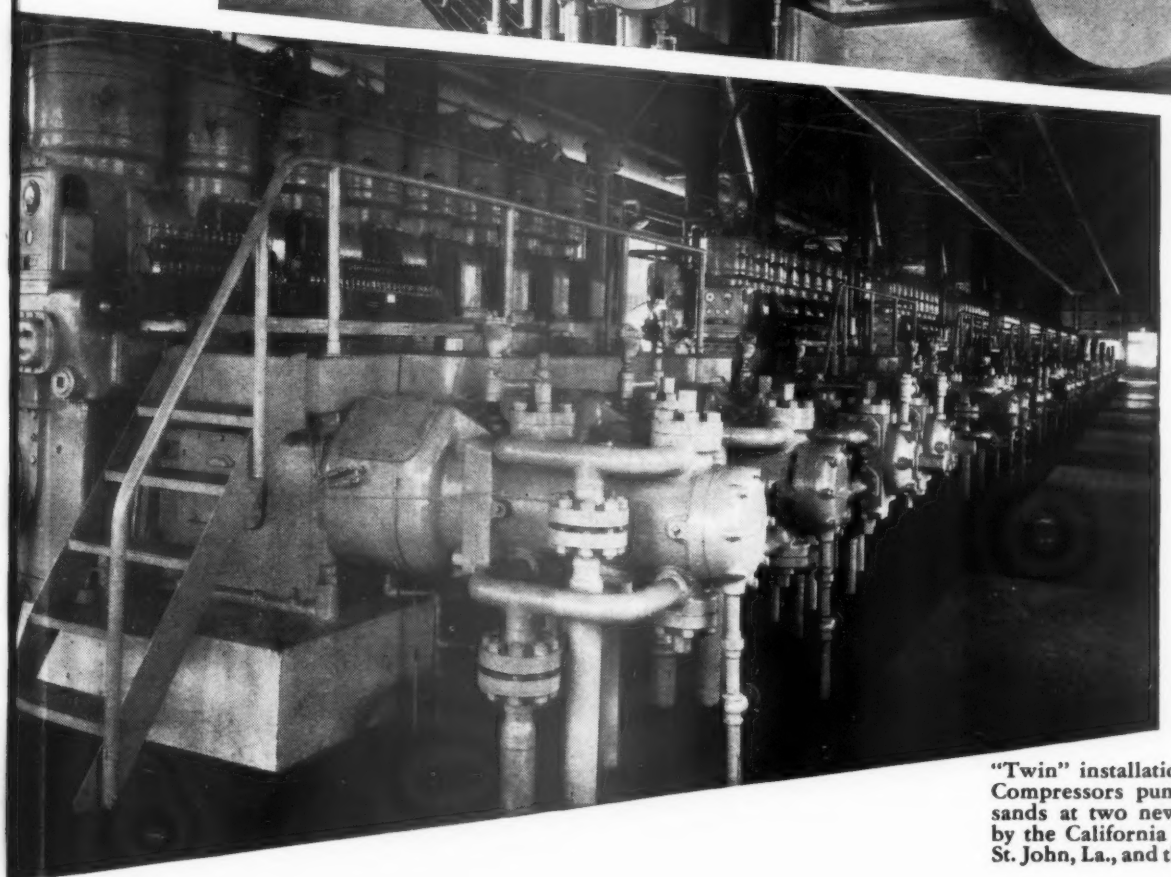

"Twin" installations of Clark Right Angle Compressors pump dry gas back into the sands at two new cycling plants operated by the California Company. One is at Lake St. John, La., and the other at Cranfield, Miss.

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FIG. 2. Apparatus for determining purity of hydrocarbons by measurement of freezing points. About 5 ml of the hydrocarbon is placed in an inner vacuum flask (right) and stirred by an arm operated by overhead electric motor. Refrigerant for cooling is contained in outer vacuum flask. Observations of time and temperature are made (using a platinum resistance thermometer at bottom center of inner flask), starting with liquid above freezing point, continuing until stirring becomes difficult.

FIG. 3. A view of the distillation room at the National Bureau of Standards showing the 18-ft distillation columns used in the separation of hydrocarbons from petroleum. Between the columns are situated the service outlets, controlled pressure manifolds, electrical power controls, and receiving assemblies. The instruments in the foreground are for the thermometric system. Fifteen distilling columns are operated 24 hours a day, every day in the year.

operations of the cooperative program to be continued by the API Research Project 6 and the Hydrocarbon Standard Samples Laboratory at the National Bureau of Standards. At present, new materials for purification are obtained as needed by specific arrangement with the several participating laboratories, of which the API Research Project 45 at the Ohio State University continues to make by far the largest number of contributions.

The goal of the cooperative program was one liter of API-Standard material of 99.8 mole per cent purity for use as standard samples plus 0.2 liter of higher purity for API-NBS samples. The API-NBS samples are a series of highest-purity hydrocarbons, the preparation of which was begun in 1943 as a joint effort of the API Hydrocarbon Research Project (now the API Research Project 45) at the Ohio State University and the API Research Project 6 at the National Bureau of Standards. These samples are available on loan to qualified investigators for the measurement of needed properties. The API-NBS samples and the data obtained from them are handled through the API Research Project 44 on the "Collection, Analysis, and Calculation of Data on the Properties of Hydrocarbons" at the National Bureau of Standards.

Complete details of the experimental procedures and apparatus used in the work on purification, purity, and freezing points have recently been published (NBS Research Papers 1734, 1752, and 1760), together with results on more than 100 different hydrocarbons. In these investigations, the purity of the various fractions of a hydrocarbon in preparation, as well as the final best lots, are determined from measurements of freezing points made with a precision apparatus involving a platinum resistance thermometer and bridge. The procedure utilizes time-temperature observations of the liquid-solid equilibrium in freezing and melting experiments (NBS Research Paper 1676).

One of the most powerful tools for evaluation of the purity of chemical compounds is measurement of the freezing point. Two isomeric hydrocarbons having the same boiling point, density, or refractive index can be mixed without significant change in these properties; but, if two isomeric hydrocarbons having the same freezing point are mixed, the change in freezing point will usually be very large.

Accurate measurements of the freezing points of hydrocarbons are made at the National Bureau of Standards with special apparatus (Fig. 2) utilizing time-temperature freezing and melting

☆ ☆ ☆

According to an official of a major oil company, the present investment per daily barrel of refined petroleum products has increased since 1939 from $900 to $1500 for crude topping and catalytic cracking plants; from $600 to $1000 for crude topping and thermal cracking; from $180 to $300 for skimming plants; from $2100 to $3500 for synthetic oil from natural gas, and from $3000 to $5500 for synthetic oil from coal.

WHEN PIPING PLANS CALL FOR *Speed* – SPECIFY

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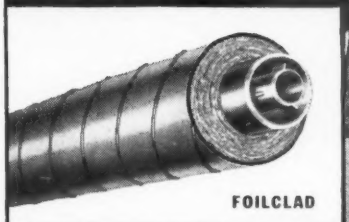
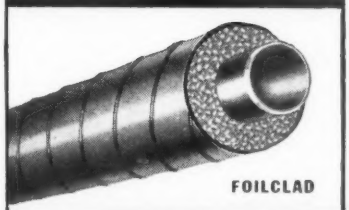


FOILCLAD

INSULATED, JACKETED PIPE

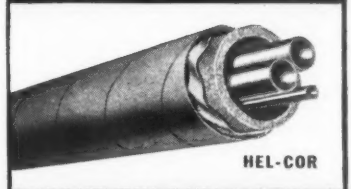
Pipe supported within a pipe, either to carry heating or cooling medium, other for process fluids.



FOILCLAD

REFRIGERANT LINES

Low temperature cork insulation, coated with asphalt and tension-wrapped with foil covering.



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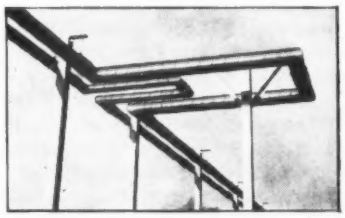
● Every construction engineer knows the loss of time, the hazards and the cost of sundry materials needed for insulating, waterproofing, wrapping and wiring of overhead pipe lines, when these operations have to be done on scaffolding. The Ric-wiL Unit method of installation eliminates most of this costly field work, makes possible phenomenal speed on the job and assures a permanent trouble-free system. Prefabricated 21-foot sections are delivered to job site, complete with pipe, insulation, couplings and accessories, and ready for hoisting onto trusses. Several units may be coupled on the ground before installation, minimizing overhead work under difficult conditions. On one job, 1500 feet of Ric-wiL Units were installed in place on channel steel uprights—with pipe welded and ready for couplers and insulation between units—*in only two working days.*

In Ric-wiL Foilclad Units, insulation is machine-coated with high temperature asphalt, then tension-wrapped with asbestos felt. This is followed by second coating of asphalt and finally covered with spiral tension-wrapping of foil, forming perfect bond with asphalt coating. In Ric-wiL Hel-coR Insulated Pipe Units, pipes and insulation are housed in 16 gauge helically corrugated galvanized iron housing.

Ric-wiL's full line of factory prefabricated accessories includes expansion devices, anchors, fittings, drip legs, valve connections and all other accessories required for fast, economical field installation.



Typical installation showing double overhead expansion loop for steam and return line.

For further information on Ric-wiL Insulated Piping write The Ric-wiL Co., Dept. 1482.

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INSULATED PIPE CONDUIT SYSTEMS

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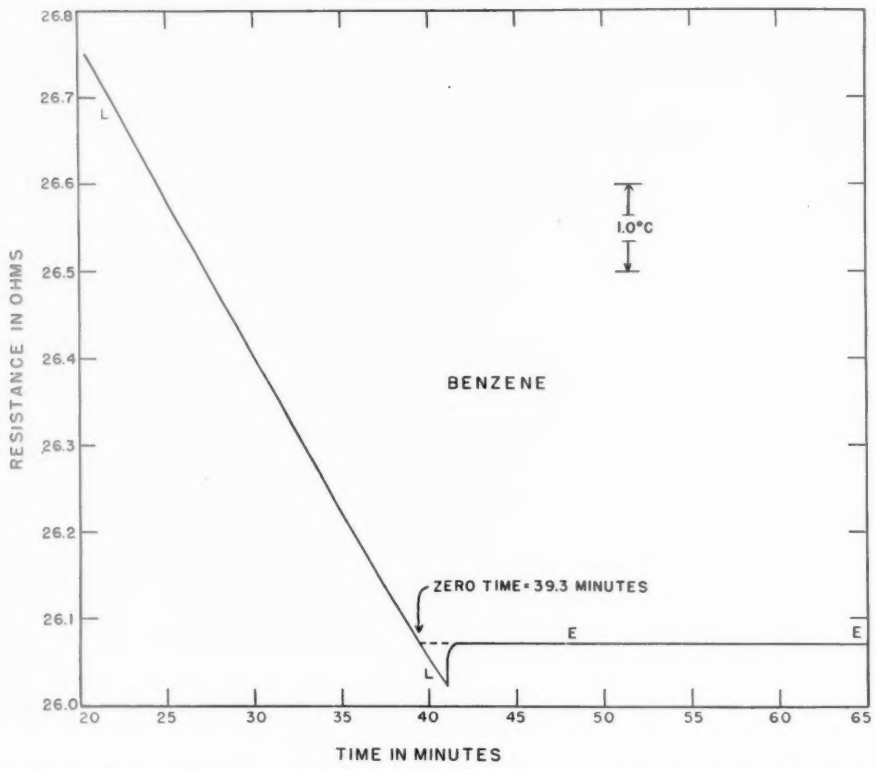

FIG. 4. Time-temperature cooling curve for determining "zero" time in an experiment at the National Bureau of Standards on a sample of benzene of purity 99.4 mole per cent. The scale of ordinates gives the resistance in ohms of the platinum resistance thermometer, and the scale of abscissas gives the time in minutes. The line EE represents the equilibrium portion of the freezing curve. Zero time is given by the intersection of the liquid cooling line with EE extended.

curves. About 5 ml of the sample to be examined are placed in an inner vacuum flask surrounded by the refrigerant and stirred by an arm operated longitudinally by an overhead electric motor. Observations of time and temperature are made (using a platinum resistance thermometer at bottom center of inner flash), starting with the temperature of the liquid above the freezing point and continuing until the stirrer begins laboring. By plotting these values, using a suitable scale on the temperature axis, it is possible to determine graphically the "zero time" at which crystallization would have begun in the absence of undercooling. The corresponding temperature value is then the true freezing point. The calculation of purity is made from the measured freezing point together with the value of the freezing point for zero impurity and the cryoscopic (freezing) constants.

Some substances, such as ethylbenzene, do not normally yield equilibrium time-temperature freezing curves. For these compounds, the determination of the freezing point is made from melting curves. In general, the procedure is the same as that for freezing experiments except that, when stirring becomes difficult, the cooling bath is replaced by an appropriate warming bath.

The purifications are usually accomplished by a series of two, three, or four distillations, regular or azeotropic, at high efficiency and high reflux ratio. The blending of distillate for subsequent distillation, as well as for the final product, is normally done on the basis of the purity determined by measurement of freezing points.

For such high-degree purification of hydrocarbons, certain facts must be kept in mind. A logical simple purification following preparation of a given hydrocarbon concentrate will usually remove all impurities except close-boiling isomers. In a series of fractions obtained from a distillation at high efficiency of a hydrocarbon containing close-boiling isomers as impurities, the fractions of highest purity will be beyond or ahead of the middle portion of the distillate as frequently as in the middle portion. That is to say, the purest material is not always in the middle of the distillate, as in the case of the normal octane. For example, the purest material is obtained near the beginning of the distillation of 2, 2-dimethylhexane, while the purest material is at the very end of the distillation for cis-2-pentene. For producing material of highest purity, the blending of the fractions of distillate can be done safely only on the basis of the freezing points of selected fractions. One of the important products of this work is the precise evaluation of the freezing points for zero impurity for the given hydrocarbons, together with values of the appropriate cryoscopic (freezing) constants.

☆ ☆ ☆

A quarter century ago Sir William Ramsay, foremost English chemist of his day, indicated how coal could be converted into gas at the mine. It remained for the Russians to do it commercially. By the outbreak of World War II one station alone had produced more than 30 million cubic meters of gas, and there were others.

The Hydrocarbon Standard Samples Laboratory is charged with responsibility for transferring and sealing "in vacuum," certifying, and packaging all API-Standard hydrocarbons that are made available as NBS standard samples in the cooperative program of the National Bureau of Standards and the American Petroleum Institute. (See NBS Research Paper 1744 for complete report.) The operations involved in this work are exacting in detail and require the utmost care to avoid contamination or loss of the high-purity material. The hydrocarbons are completely degassed, transferred through the vapor phase at room temperature, and sealed, after refrigeration, in glass ampoules "in vacuum." At present nearly 2000 units per month are being sealed in this laboratory. (Fig. 3.)

Two sets of apparatus currently in operation in the Bureau's laboratory transfer and seal "in vacuum" hydrocarbons having normal boiling points below about 175 C. In order to handle less volatile hydrocarbons, a new apparatus has been developed for sealing "in vacuum" hydrocarbons of normal boiling points above about 175 C.

As of July 1, 1947, 119 compounds had been completed as hydrocarbon standard samples. Thirty are now in process of purification, 46 are on hand for purification, and 36 are scheduled for delivery to the National Bureau of Standards (mainly from the API Research Project 45). New hydrocarbon standards are being completed at the average rate of one compound every eight working days.

In addition to purity, three compounds of the original NBS list are certified with respect to values of density and refractive index* and may be used to calibrate refractometers, picnometers, and density balances, as well as spectrometers. These standards are No. 217, 2, 2, 4-trimethylpentane; No. 218, methylcyclohexane, and No. 211a, toluene. Standard sample No. 217, 2, 2, 4-trimethylpentane, is also certified for calorimetric heat of combustion, primarily for calibrating equipment used to determine the heating value of gasoline and other liquid fuels.

*Samples are certified with respect to values of density. for air-saturated material at one atmosphere, at 20, 25, and 30 C, to ± 0.00002 g/ml; and with respect to values of refractive index, for each of 7 wavelengths (helium 668 and 502, hydrogen 656 (c) and 486 (F), mercury 546 (e) and 436 (g), and sodium 539 (D_1, D_2) at 20, 25, and 80 C to ± 0.00002.

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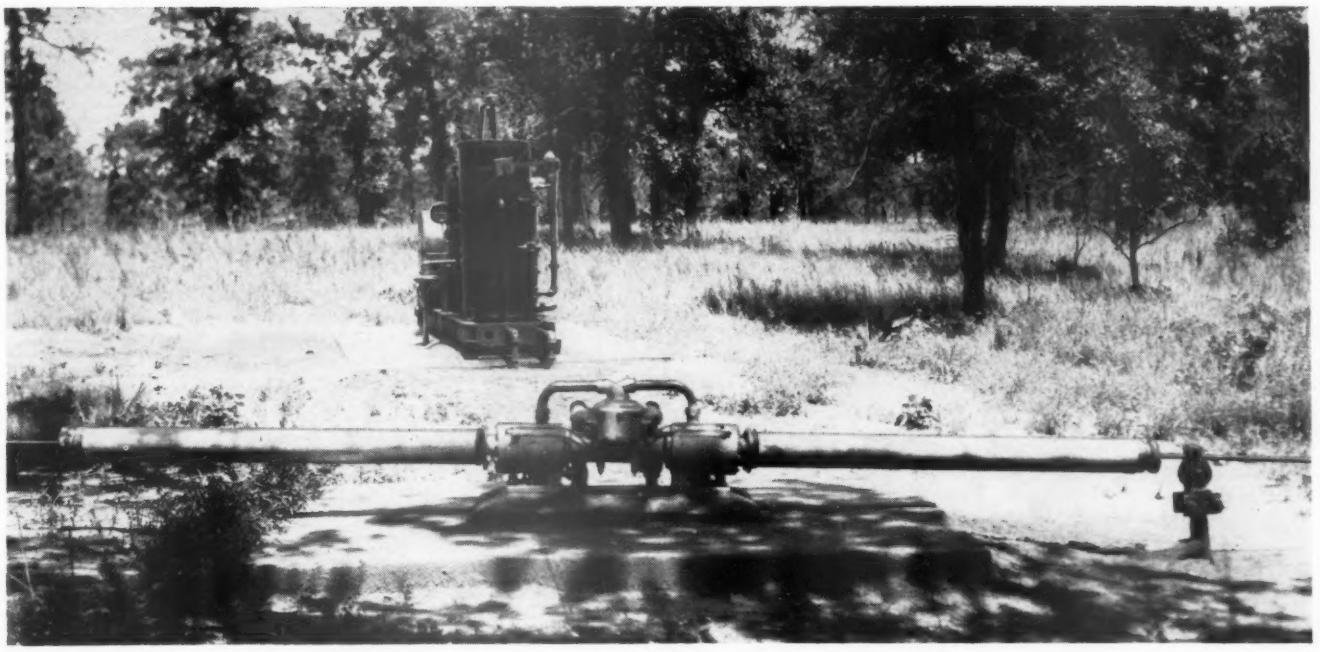

FIG. 6.

Hydraulic pumpers for shallow oil wells*

By A. A. HARDY, Chief Engineer, W. C. Norris, Manufacturer, Inc.

IT HAS long been recognized that the transmission of power by hydraulic means, when properly designed, offers the advantages of flexibility, higher efficiencies, low wear, and low maintenance rates when compared to power transmission through an entirely mechanical system of metal-to-metal contacts. During World War II the technical development of hydraulic power transmission was advanced tremendously and it was applied in many new fields. The design of fluid couplings and torque converters, of hydraulic transmissions and hydraulic controls had wide application in our weapons of warfare. The present dependability of this type of power transmission is demonstrated by the fact that most of the vital controls on our aircraft today are hydraulically actuated.

● **Hydraulic pumpers.** The application of hydraulic power to oil-well pumping mechanisms dates back almost to the inception of the oil business. Until the past few years, however, there have been very few such devices that could be considered successful; all this in spite of the fact that there have been granted hundreds, perhaps thousands, of patents relating to "hydraulic pumping mechanisms." One possible reason for this seemingly slow development lies in the fact that while the flow of fluid through pipes seems to be a fairly simple thing, when such flow occurs through rather complicated control valves and where reversal of flow is required, peculiar and unpredictable behavior often becomes evident. Only a close and careful study of the problem in hand will disclose the laws and rules that must be followed to effect the successful design.

Quite naturally most of the presently developed hydraulic pumping units have been designed for single well applications. Incidentally, all remarks made herein refer only to surface pumping equipment, not subsurface devices. In these applications it becomes obvious that the logical form the pumper should take is that of a vertical cylinder mounted directly over the wellhead. Hydraulic cylinders have been applied to the conventional walking beam pumper structures, but one important inherent advantage of single well hydraulic pumping is thereby sacrificed, that of the long slow stroke. Walking beams are limited in stroke by the angularity they impose on the polished rod.

One of the major problems in designing such a pumper is the means to be used to effect the counterbalance required for efficient pumping. This is usually done in either one of two manners. The well can be counterbalanced by means of dead weight, which calls for a second hydraulic cylinder, or by means of a pneumatic chamber. Both devices have their drawbacks. If dead weight is used, a very tall, high structure is required to support the weight and give the required stroke, or a deep hole in the ground becomes necessary with its attendant troubles. If the pneumatic chamber is used, it becomes necessary to provide some means such as an air compressor to start the unit initially and to make up the air absorbed in the oil. Because of these required accessories and the controls that go with them, the cost of single well pumpers has so far required that they be applied only to very deep and heavy wells where the cost of competitive equipment is also in the higher brackets, and where the inherent advantages of the hydraulically cushioned, long slow stroke for greater ultimate production, fewer rod breakages and lower maintenance, offset the greater initial cost of this type of equipment. This circumstance of cost has existed until recently. With present day advances in hydraulic design, it may not exist tomorrow.

Hydraulic pumpers for shallow oil wells have been made possible and practical through the development of a hori-

*Presented before The American Society of Mechanical Engineers, Houston, Texas, October 5-8, 1947.

zontal, double-acting hydraulic cylinder that is placed in the conventional surface rod line between two or more wells. (Fig. 6). By applying hydraulic power oil under pressure to this cylinder, it will reciprocate the surface rod lines in the usual manner, from 1 to 20 spm, which rod lines operate conventional pumping jacks to pump the wells. The main economical advantages of this system, when compared to single well hydraulic pumpers for shallow wells, lies in the fact that no counterbalance device is required, as the dead weight of one well will counterbalance the other well; and the initial cost of the single pumping cylinder can be prorated between the number of wells it pumps, as can the cost of the hydraulic power unit, which, incidentally, can be designed to handle several such cylinders. Further economies of this type pumping will be taken up later.

● **Volume of power oil required.** We have dubbed this horizontal hydraulic rod line pumper the "Hyd pumper," and I will, therefore, refer to it hereafter as such for brevity. The requirements of the Hyd pumper for quantity of fluid are dependent only on the number of strokes per minute desired for the rod line. Repeated volume tests indicate that 2.17 gal of oil are required for one complete cycle or stroke at a 24-in. piston travel, and an average speed of 8 spm. This indicates a volumetric efficiency of 94 per cent. For purposes of estimating the required hydraulic pump capacity in gallons per minute, we use a figure of two and one-half times the number of strokes per minute required for the rod line. This figure is then multiplied by the number of Hyd cylinders the power unit is to serve. For instance, if we have a lease with six wells pumped by three Hyd cylinders, and the producer desires that the wells be pumped at the rate of 12 spm, we would require a hydraulic pump of large enough capacity to handle $2\frac{1}{2} \times 12 \times 3$ gpm, or 90 gpm.

● **Pressure of power oil required.** The pressure required at the Hyd cylinder to actuate the rod lines is a function solely of the net rod line pull and the area of the Hyd pumper piston. The net rod line load equals the fluid load lifted at the well, plus the impulse load, plus the rod line friction. The Hyd pumper cylinder is 3¾ in. diam with an 1¼-in. rod giving a net area of 9.8 sq in. For purposes of estimating we divide the rod line load by ten to obtain the pressure required. This is about 2 per cent low, but inasmuch as we must add about 75 psi to the result to take care of rise in pressure for tripping at the end of the stroke, the results are satisfactory.

The Hyd pumper can be installed as a single well unit very satisfactorily from the standpoint of operation, using a stone boat or counterweight on one end instead of the second well. The economies of such an installation, however, are questionable, except in special cases. The two-well installation is very simple, and more than two wells can be easily handled by using swings, although a little more care should be used in balancing a system like this.

In figuring rod line loads, the wells to be pumped with each Hyd cylinder should be divided into the two opposing groups taking into consideration their weights, pumping period, and future life characteristics, as well as any other production factors that may be evident. Next the rod line pull for each of the opposing systems should be figured and calculations for pressure required then made on the heavier system.

The lighter system can be counterbalanced later to equal the same figure. In figuring polished rod loads, we have found the Slonneger[1] formula[2] to be quite satisfactory. To obtain the required effective rod line pull to be exerted by the Hyd cylinder, first calculate the polished rod load, then deduct the dead weight of the sucker rods and counterbalance (which, incidentally, should be included with the weight of the sucker rods where used, in order that proper impulse factor can be applied). This figure should then be multiplied by the multiplication ratio of the jack, if the polished rod stroke is greater than the rod line stroke, and to this figure should be added the rod line friction and the friction of swings and multipliers where used. If multipliers are used, care should be taken to adjust the pull in accordance with the multiplication used. Please note that the weight of the rods and counterbalance is included in the original calculation, then deducted so that the proper impulse factor can be applied. It is deducted as mentioned before because it is counterbalanced completely by the opposing well or wells and has no effect other than inertia on the Hyd cylinder. It, therefore, follows that where the dead weight of opposing wells is not the same, counterbalance weights should be added to the lighter wells. Where the fluid loads on two opposing wells are not equal, one-half the difference of the two fluid loads should be added as counterbalance to the lighter well.

In figuring rod line friction, the values given in Table 1 may be used. It is based on flat rod lines with fairly well lubricated rod line carriers. If the rod lines approach the catenary curve, proper judgment should be used in reducing the assumed loss. Friction through swings varies with the angle of the swing. Assuming well designed and lubricated swings, the loss will vary from about 0.1 per cent of the gross rod line pull for 15-deg swings, to 1 per cent of the gross rod line pull for 180-deg swings. Multipliers will require about 0.5 per cent of the gross rod line pull. These figures are based on gross rod line pull, which includes the dead weight of the sucker rods. For our purposes, when we deduct such dead weight and use the net effective pull as herein outlined, the above friction losses can be doubled under average conditions with little loss in accuracy.

TABLE 1—Rod line friction loss.

Pull rod size, in.	Friction loss, lb per 100 ft of rod line— Wooden carriers	Average anti-friction carrier
⅝	30	
¾	44	14
⅞	81	17
1	116	21

In outlining the methods of estimating rod line loads, we have assumed that the opposing ends of the rod lines are balanced. This is the ideal or proper manner in which to operate. So far as the Hyd cylinder is concerned, it will operate satisfactorily under unbalanced conditions, the only result being that the pressure required in one direction will be greater than that required in the opposite direction. As a matter of fact, we have experienced occasions of rod line breaks, and the pumper has continued operating, where the hydraulic relief valve was set high enough to permit it to do so. On the other hand, if it is desired that the unit stop under such conditions, it will be caused to do so by setting the relief valve slightly above the maximum pressure required for normal operation.

● **Selection of the power unit.** Summing up the above we find that the quantity of power oil required in gallons per minute is equal to the number of strokes per minute required for the rod lines times 2½. The pressure required in psi *at the Hyd cylinder* equals the *net* rod line pull divided by 10 plus 75. To this pressure should be added the line friction loss of the hydraulic oil from the power unit to the Hyd cylinder. This can be figured by conventional means.

If more than one Hyd cylinder is used for one power unit, flow control valves or needle type adjusting valves must be used to prevent one cylinder from robbing another. This is very important.

A typical power unit is shown in Fig. 5. It consists of a rotary high pressure pump, V-belt driven by a horizontal single cylinder engine, a reservoir open to atmosphere, a high pressure balanced piston type relief valve, and the necessary piping, all skid mounted. The size of the engine and pump are determined by the gallons per minute and pressure required as outlined above. The reservoir should have a capacity at fluid level of 1½ to 2 times the gpm. Various controls may be included as desired, such as low level cutoff as shown and high temperature cutouts. Our experience has indicated that no cooling devices need be included for the oil, as convection and conduction, particularly in the lines from the power unit to the pumper cylinders, is ample. We do recommend a roof of some sort over the power unit to keep the direct rays of the sun off the reservoir tank.

● **Design of the Hyd pumper.** The original design work on the Hyd pumper was done by two men[3] working for

[1] J. C. Slonneger, Continental Supply Company, Dallas, Texas.

[2] Polished rod load =

$$(W_r + W_o)\left(1 + S\,\frac{Spm}{5400}\right)$$

Where:
Wr = weight of the sucker rods,
Wo = weight of the oil = $0.34D^2 \times L$,
S = polished rod stroke, in.,
Spm = strokes per minute,
D = diameter of the plunger, in.,
L = depth to fluid level, ft.

[3] Clint Cross and Barr McDermott.

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the company with whom the writer is employed. The writer did not enter into the work until the design was fairly well along. The basic idea of the device is not ours. One of the prime objectives of design was to eliminate all adjusting points possible in the field and to keep it as simple as possible. Four completely different working models were built and tested before the final design was approved. Basically, the final design of the Hyd pumper consists of a double acting hydraulic cylinder whose reversals are effected by means of a conventional straight-line, lobed, piston-type four-way master valve. The reversals of the four-way master valve, and in turn the main piston, are effected by a pilot valve that alternates the intake and exhaust pressure on the ends of the four-way master valve. This pilot valve is also a four-way valve of the same type as the master four-way valve. The reversals of the pilot valve, in turn, are effected hydraulically by small spring loaded pistons inserted in each cylinder head of the main cylinder. At the end of the main piston stroke, the main piston depresses this small inserted piston, which in turn forces oil under super-pressure to one end of the pilot valve piston and opens the other end of the pilot valve piston to exhaust, thus causing its reversal. This system of effecting reversals is entirely conventional with all reciprocating hydraulic cylinders with the exception of the means used to reverse the master valve. In other mechanisms this is sometimes done mechanically through linkage and levers and sometimes hydraulically, using a pilot valve as in this case. In those mechanisms where it is done hydraulically, the reversals are effected in various manners such as opening one end of the pilot valve to exhaust pressures or spring loading it in one direction using intake pressures to depress the spring. In the case of the Hyd pumper, however, we found that by pressurizing or actually super-pressurizing one end and venting the other, it gave us the positive action and dependability required, and was effected with no more moving parts. In Figs. 1, 2, and 3 we have shown the flow diagram of the Hyd pumper in various positions of its cycle. Fig. 1 shows the main piston approaching the end of its travel towards the right with the small pilot valve piston at the top and also at the right-hand position. The pressured oil can be traced from the intake through the pilot valve, to the left hand end of the large master valve below it, holding the master valve in its right hand position. This allows the pressure oil to flow through the master valve to the main cylinder, forcing it to the right. In Fig. 2 the main piston has reached the end of the main cylinder and has depressed the small inserted piston in the cylinder head. This small inserted piston has pressurized the oil trapped behind it and forced it into the right-hand end of the pilot valve piston, and at the time has opened the left-hand end of the pilot valve piston to exhaust by means of a small land in the small

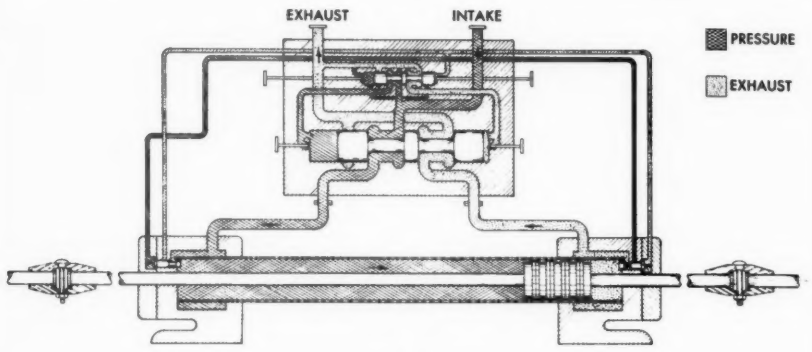


FIG. 1.

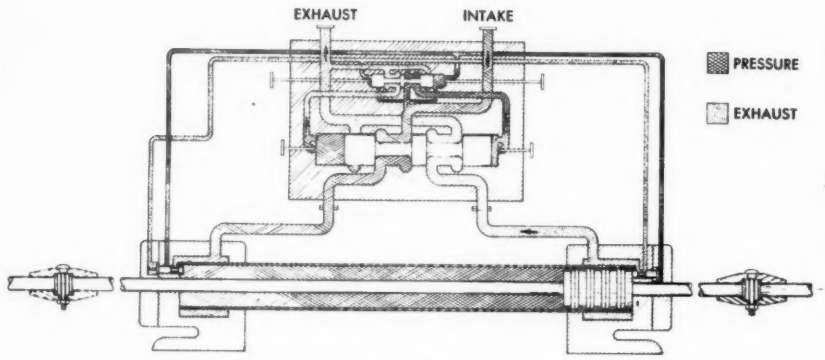


FIG. 2.

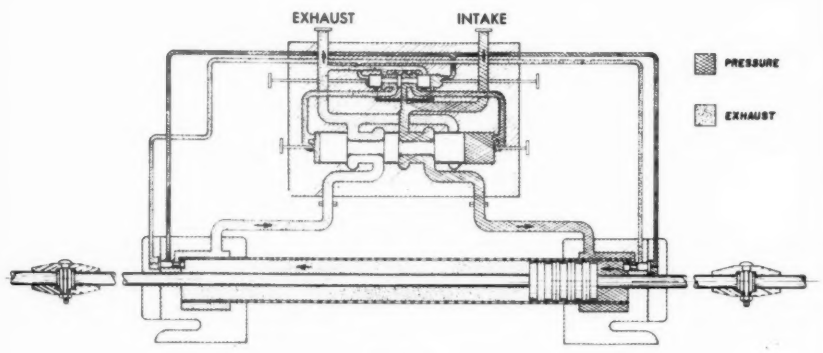


FIG. 3.

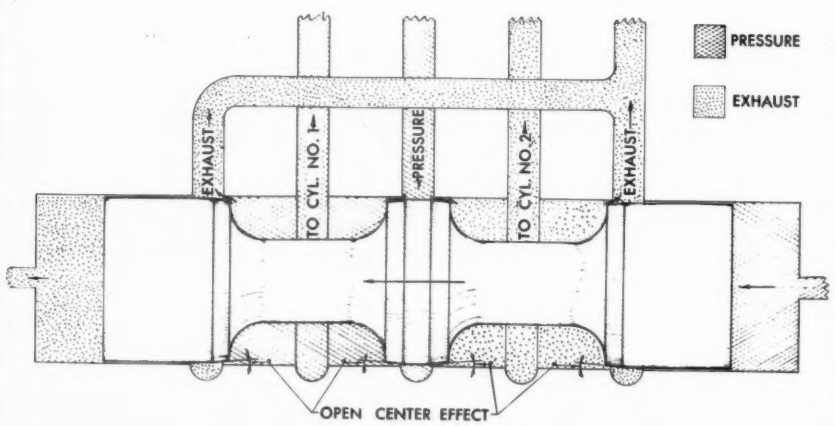
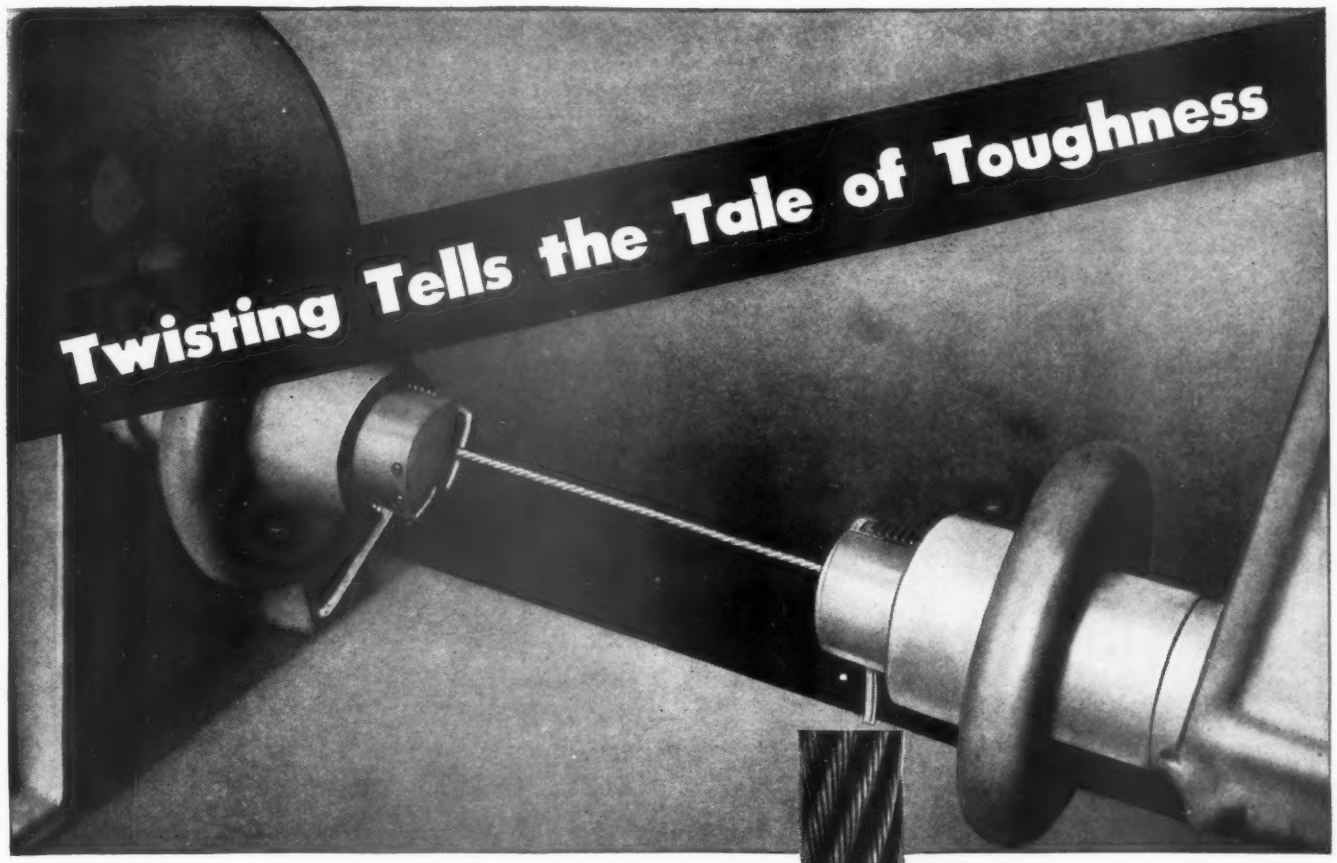


FIG. 4.



Here we see an 8" piece of rope wire being twisted on its own axis. The revolutions necessary to break the wire are counted and only those coils are accepted which test at least 10% above American Petroleum Institute specifications for wire rope. In addition to being an indication for toughness, the torsion test reveals whether the wire is free from steel defects such as seams and cups.

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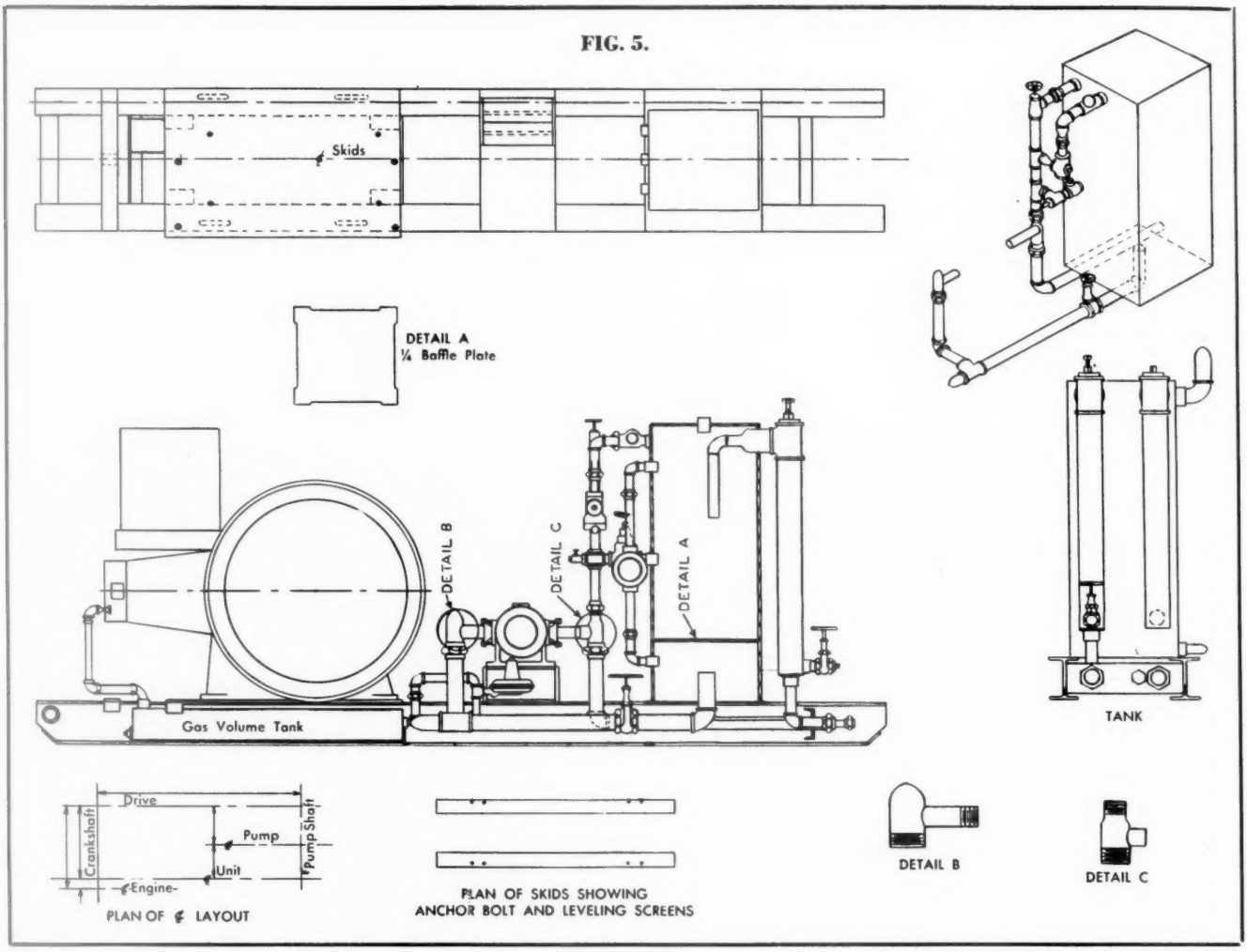
FIG. 5.



inserted piston, which opens an orifice as it is forced back by the main piston.

The reversals of pressure on the ends of the pilot piston cause it to move to the left as shown, which movement in turn lines up the center ports in such a manner as to allow the pressure oil from the intake to the right-hand end of the master valve and at the same time opening the left-hand end of the master valve to the exhaust. This causes the master valve to move to the left. Fig. 2 shows this condition at the instant after the pilot valve has moved and before the master valve has moved. Fig. 3 illustrates the conditions after the master valve has moved to the left, which in turn redirects the flow of the main oil streams to the alternate ends of the main piston, causing it to travel to the left. This action is all repeated in reverse at the other end of the cylinder. The two rods extending to the outside from each end of the pilot valve are simply manual means of reversing the pumper in mid-stroke. This device enables the operator to pick up his wells.

Perhaps the most difficult problem that we encountered in the design of the Hyd pumper was the problem of smooth, gradual reversals. There are several means of accomplishing this. It can be done by controlling the rate at which the master valve spool travels when reversals occur. This can be done by installing a check and needle valve in the fluid passage to each end of the valve, allowing free flow in and metered or restricted flow out. This is illustrated in the figures. It can also be done by allowing what is called an "open center" effect in the master valve spool. This is illustrated in Fig. 4. The valve is shown in mid position, at which point the pressured oil is flowing in both directions, which gives the cushion effect sought to the travel of the main piston. A third means of obtaining smooth reversals is to cause the main piston to overtravel the exhaust port, thus entering the end of the cylinder where the oil thus trapped is allowed to escape through a highly restricted but adjustable needle valve. All three of these methods are used in the Hyd pumper, enabling us to get any degree of smoothness desired on the reversals. An interesting sidelight to this question is that one operator insisted on sharp, jerky reversals of the rod line, explaining that such action kept his valves in the bottom hole pump free, thus saving him considerable work each day.

In experimenting with the Hyd pumper we have learned two or three rules governing the action of hydraulic power fluid, which we gladly pass on here:

1. Fluid velocities in all fluid passageways should be held to not more than 10 fps. By so doing excess loss in friction and efficiency is eliminated. Velocities of the oil in the pilot circuit should be held to about 5 fps for smooth dependable action.

2. A pilot piston is necessary if the master valve is to be reversed hydraulically. The reason for this is obscure, but the necessity is none the less real. We were informed of this rule before we started our design, but we found out for ourselves that it is true.

3. An open center master valve should be used to avoid high peaking pressures at the reversals. As the angle of open center is increased, the peaking pressures are decreased even to the point where a drop in pressure will be obtained at reversal; however, volumetric efficiency also decreases as the open center increases. Consequently, a happy medium must be selected and decided upon.

4. Unforseen pressure surges can occur at surprising places. As a consequence, never decide on a feature of the design until it has been actually tried under all possible conditions. Power hydraulics can be unpredictable.

● **Economic aspects of the Hyd pumper.** The economies to be realized through the installation of a Hyd pumper fall into two classes. In the first place, we have the economies effected in initial investment. If we consider new single well installations, we must weigh the cost of the Hyd cylinder, the power unit

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including engine, rotary pump, reservoir tank and fittings, a short rod line, a stone boat or counterbalance, and a pumping jack against a conventional pumping unit. The Hyd pumper installation in this case will be equal in initial cost to 25 per cent greater, depending on the class of pumping unit procured. If, however, even on a single well installation, the operator has a jack installed at the well and has the necessary rod line and perhaps a small engine available, then a definite savings can be made by making use of this material in connection with a Hyd pumper.

On the average two-well installation, one study indicated a savings of 20 per cent in favor of the Hyd pumper. Here, of course, the cost of the single power unit and single pumper was prorated over the two wells. In another case where six wells were to be pumped with two pumper cylinders and one power unit, a savings of 40 per cent was indicated.

Of course, each case should be studied on its own merits. Factors that favor the installation of the Hyd pumper are:

1. Multiple well installations where the cost of one power unit can be spread over several wells.
2. Pumping jacks on hand and set in some cases.
3. Rod lines, swings, and other surface equipment on hand.

Factors that do not favor the installation of the Hyd pumper are:

1. Excessively long rod lines, where pull rods and jacks must be purchased.
2. Requirements for long strokes above, say, 54 in.

The second class of economies to be realized through installation of Hyd pumpers is the savings effected through economical operation and through savings in labor. The writer has at hand a "Dynamometer and Well Study Report" prepared by Johnson and Fagg,[4] wherein they record an efficiency study made by them on three wells averaging 2900 ft equipped with standard rig fronts. They measured the horsepower input to the motor with a recording ammeter and the polished rod horsepower by means of an electrical dynamometer.

The report reads as follows:

Well	Input hp	Polished rod hp	Loss	Rig and motor efficiency, per cent
"A"	7.18	0.7	6.48	9.75
"B"	6.3	1.25	5.05	19.8
"C"	24.5	5.65	18.85	23.0

Surprisingly low as these efficiencies appear, some of our old band wheel power installations are lower. If cost of power is an economic consideration, then appreciable savings can be made by replacement with new, modern equipment. Likewise, if repair of some of this old equipment becomes imminent, savings might be made through installation of new equipment rather than repair of the old. This is the field of application into which the Hyd pumper fits particularly well.

Accurate and extensive field test of efficiency of the Hyd pumper has not been completed, but shop tests on a rather elaborate testing stand show volumetric efficiencies averaging 94 per cent and overall efficiencies between 74 to 87 per cent. This high efficiency is due, of course, to the fact that all moving parts are totally enclosed in a bath of clean oil; moving parts are small in number and size; oil velocities and, as a consequence, fluid friction losses are kept low.

Perhaps the major savings to be effected is the savings in labor. Usually old leases have a number of part time wells, requiring more or less constant attention on the part of a pump operator. The reliability and low maintenance rate of the Hyd pumper will permit an operator to adjust length of stroke, number of strokes per minute, and size of barrel in the well so as to arrange 24-hr operations. By so doing, it is possible to limit the visits of the pump operator to twice or even once a week. In this manner one man can watch or handle many times as many wells as was previously customary. In following this policy one major company has shown a monthly savings on a lease near the writer's home of well over $300 per month.

In conclusion, the compactness, simplicity, trouble-free characteristics of this hydraulic pumping cylinder qualify it particularly for application in shallow stripper fields where initial cost and cost of operation are both prime considerations.

[4]L. W. Fagg and D. O. Johnson, Johnson-Fagg Engineering Company, Tulsa, Oklahoma.

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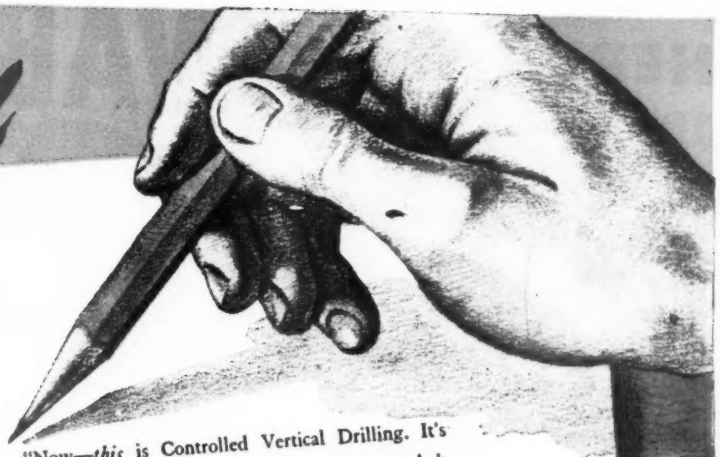

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"Now—*this* is Controlled Vertical Drilling. It's where the driller makes plenty of hole because he's always using the correct weight and speed—*straight* hole because he never lets it get beyond the critical angle. Critical angle? That's the angle at which the forces which cause hole deflection really become established. It varies with the size of the hole, drill collar, and so on, but it's always small. Some men figure it something less than 2 degrees: me, I'd like to keep the angle of the hole less than 1 degree. Any deviation less than that is easy to correct, but you can buy yourself a lot of grief if hole deflection gets beyond that angle.

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*Based upon the actual statements of hundreds of drillers and drilling superintendents in all parts of the country, and in many foreign fields.

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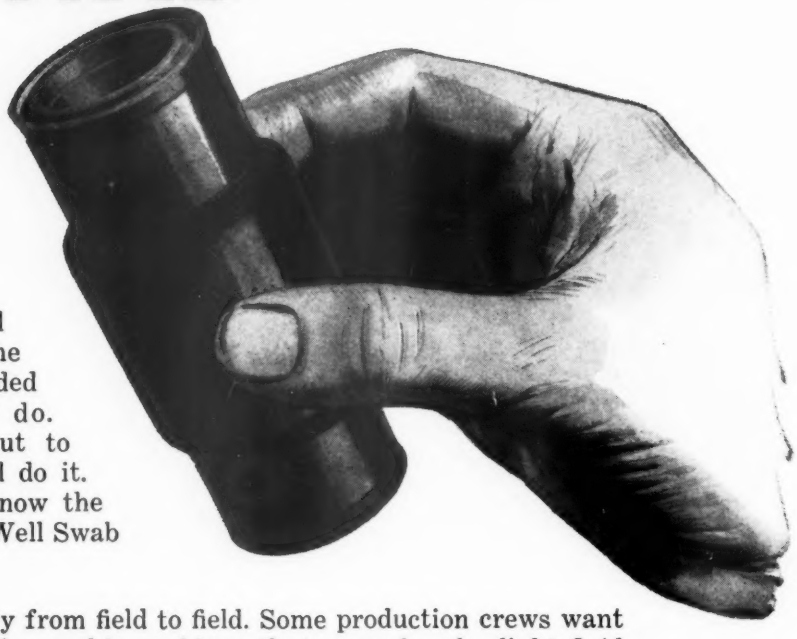

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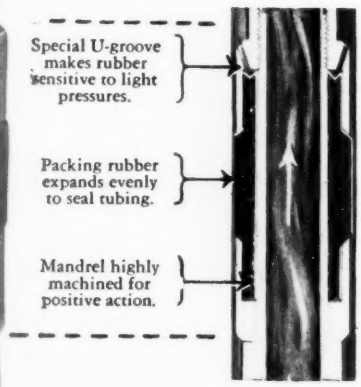
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The fuel and energy outlook in the West*

By MARION E. DICE, *Manager*, Economics Department,
General Petroleum Corporation

How adequate are the energy resources of the Pacific Coast? How long can they sustain the unprecedented influx of population that occurred during the war, continued after the war, and for which no end is in sight? Will the limit of this growth be determined by the supply of fuel and energy?

We do not think so. Other factors, particularly water supply, are more likely to set the limit than fuels. However, the problem is of such fundamental importance that it behooves the petroleum industry to take stock of the situation at frequent intervals. We must look as far into the future as possible and chart our course most carefully. The voyage is an expensive one from the standpoint of capital requirements and the shoals of the oil business are cluttered with the wrecks of shortsighted enterprises.

One of our office mottos is "The past is the best guide to the future." So let us begin today by reviewing the effects of the war and the great westward migration upon our western fuel outlook. We shall start with two fundamental facts—one of which is well known and one which is not. The population of the Pacific Coast states was 10,400,000 in 1940 and is now more than 14,500,000. This is an increase of 39 per cent in seven years whereas the normal increase would have been 1 per cent per year, compounded. This means that we have compressed 33 years of normal growth into the last seven years. But these facts are known to all of you.

The second fact may come as a surprise. It did to me. The total consumption of energy has increased 72 per cent during the period that the population increased 39 per cent. This means that the West has experienced a large increase in the per capita consumption of energy. To reach this conclusion we took the total consumption of all forms of energy—oil, gas, hydroelectric power, coal, wood, etc., converted them to a common basis by using their respective Btu equivalents, and divided by the population. (See Table 1).

It is necessary to consider all these sources of energy because they are interchangeable to a considerable extent. Some operations that use natural gas on an interruptible contract basis switch to another fuel during cold weather when gas is needed for house heating and other "firm" customers. The demand for gas and the demand for oil are therefore not independent of each other and must be considered as a whole in a study such as this.

*Presented before the 22nd Annual Meeting of the California Natural Gasoline Association, Los Angeles, California, October 10, 1947.

Of still greater importance at the moment is the interrelation between electric energy and petroleum fuels. The western states have this year experienced the lowest rainfall and snowfall in a generation. There is a demand for even more electric power than the hydroelectric plants can generate when operating to capacity, yet the amount of water behind the dams has been so deficient that the power output has been curtailed. As a result, the power companies have been burning far more gas and fuel oil than normal in their steam plants.

Thus we have had three pyramiding influences that have boomed the demand for oil and gas. First, 4,000,000 more people came west; second, the West consumed 24 per cent more energy per person; third, oil and gas were called upon to shoulder part of the load for manufacturing electric power when hydroelectric power sources were curtailed by lack of rainfall. These are the main influences at work. There are secondary influences such as the high level of employment in nearly all industries, high wages and incomes, and a large demand for all kinds of goods. These are all well known. The net result of them is a total petroleum demand in 1947 that will average more than 10 per cent above 1946 and 47 per cent above 1939-1940. Let us mention briefly some of the ways in which various influences contributed to the increase.

● **Motor gasoline.** The motoring public has been on a perfectly understandable gasoline buying binge ever since the end of rationing. Taxable sales in California for the first seven months of 1947 were 13.5 per cent higher than the record 1946 levels. New cars are becoming available in increasing numbers and old cars are being maintained in excellent repair. The automobile has become an indispensable part of western life. Its use will continue to increase in future years. The universal 5-day week and vacations with pay are enabling the average family to roam the West and enjoy travel habits that were once the privilege of few. We expect a continuation in the upward demand for gasoline for the next few years although at a slackening rate. The number of registered vehicles should increase steadily for several years. The ratio of persons per vehicle will probably fall from the present 2.9 to the 1941 ratio of 2.5 by 1950.

Motor fuel consumption per vehicle is likely to drop somewhat from the present high level by 1950 for two reasons. First, the number of two-car families will increase, and although such a family uses more gasoline than a one-car family, it does not use twice as much. Second, there should be a substantial increase in the number of miles per gallon delivered by improved engines in the next few years. We are assuming an average of 25 miles per gal for postwar models. We do not know when these will arrive. They may appear in 1948.

● **Mechanization of farms.** The consumption of petroleum on farms has grown rapidly in the 25 years, 1920-45. The number of motor trucks on American farms has been multiplied by 11. The number of tractors has been multiplied by nine. The number of horses and mules has been cut in half. Employment on farms has dropped from 10.7 per cent to 7.5 per cent of the population. At the same time, the farm production per worker has increased 42 per cent. Most of this is due to mechanization and to the release of millions of acres and manhours formerly required to grow food for horses and mules. Mechanization in the West has long been ahead of the United States average. With 5 per cent of the total number of farms in the country, the Pacific states have 6 per cent of the farm tractors and 11 per cent of the farm trucks. We expect the

The Author

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He is a member of the Los Angeles Engineering Council and has been chairman of the Southern California sections of both the American Institute of Chemical Engineers and the American Chemical Society. He is a past national president of the chemical fraternity, Alpha Chi Sigma, and is a member of Sigma Xi, Tau Beta Pi, and Lambda Chi Alpha. In the early years of bottom-hole technology, he developed the so-called "Dice Equation" for computing the pressure at the bottom of an oil and gas well from pressures measured at the surface.

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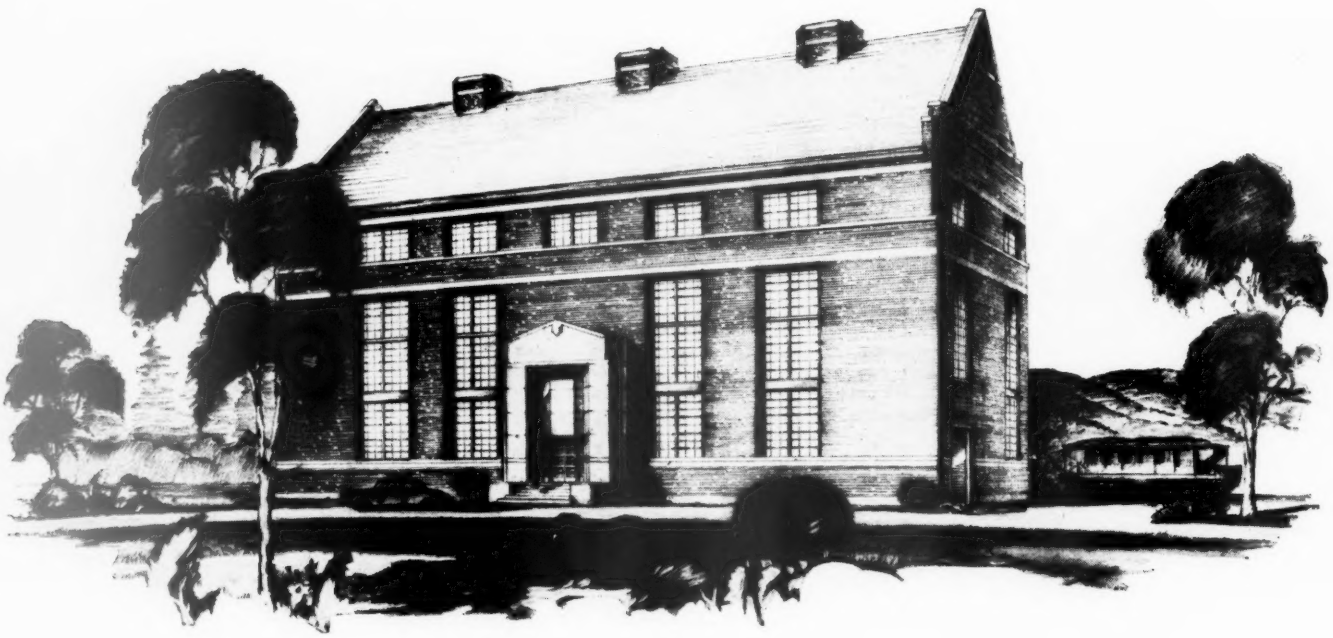

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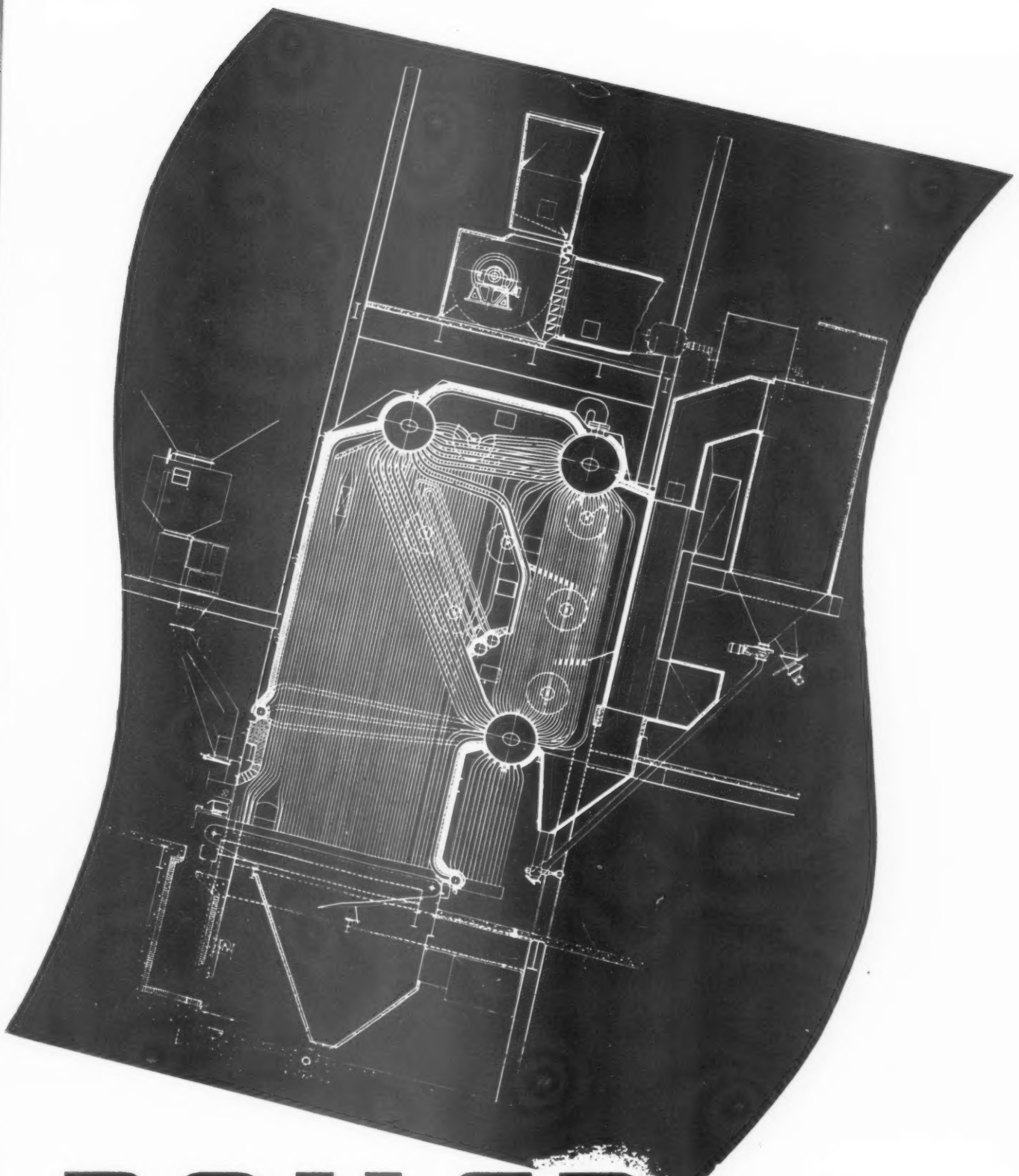

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TABLE I. Per capita consumption of energy, 1947 vs. 1940. Millions of Btus per person, Pacific Coast States

	Year 1947 (estimated)		Year 1940		Percentage increase 1947 vs. 1940
	Million Btu per Capita	Per cent of total	Million Btu per Capita	Per cent of total	
Petroleum	131.7	70.0	101.3	66.7	30.0
Natural gas	38.1	20.2	32.0	21.1	19.1
Oil and gas, total	169.8	90.2	133.3	87.8	27.4
Hydroelectric power	7.8	4.1	5.6	3.7	39.3
Coal and wood	10.7	5.7	13.0	8.5	17.7
Total	188.3	100.0	151.9	100.0	24.0
Total Btus, trillions	2722		1586		71.6
Population, millions	14.5		10.4		38.8

trend to continue through the next few years because farm income is high.

● **Domestic heating.** The number of oil heating installations in the West and Northwest has been breaking records since the war. On V-J Day there were about 230,000 distillate oil burners in use in this territory. By the end of 1946, the number had increased to nearly 300,000, a gain of 30 per cent. By the end of 1947 we expect the number to be 365,000, which means a further gain of 22 per cent in the current year, with a corresponding gain in heating oil consumption.

We are assuming that the postwar acceleration in installation of new oil burners will abate in 1948 and that the demand for heating oil will increase thereafter at a smaller rate per year.

The use of LPG for cooking and heating has increased rapidly and will continue to grow. It offers the rural and farm housewife the convenience of city gas at a price she can afford. Total sales of LPG for all purposes (chiefly domestic) are currently about 22,000,000 gal per month compared to 19,000,000 in 1946 and 9,000,000 in 1941.

● **Railroad fuels.** Dieselization of American railroads is proceeding at a rapid rate. More than 13 per cent of the locomotives in use west of the Mississippi River now are diesels, compared to fewer than 3 per cent in 1941. More than 90 per cent of all the new locomotives on order are diesels. Although they cost a great deal more than the old steam engines, they can do as much work on on barrel of diesel fuel as a steam locomotive does on three barrels of heavy residual oil. They have an additional advantage in that they do not consume water. This is important in the arid southwest. We therefore assume a continued increase in the demand for railroad diesel fuel with an offsetting decline (three times as great) in the demand for heavy railroad fuel.

Total railroad fuel requirements vary with the general level of industrial activity and with national income. If the forecasters are right, some decline is indicated over the next few years but this should be of small proportions. The chief uncertainty in predicting railroad requirements is the unsettled condition of the merchant marine. Due to high operating costs and other factors, much of the coastwise and transcontinental freight that would normally move by water is still being carried by rail. The future should see a substantial resumption of marine shipping but this does not appear likely in the next year or so.

● **Bunker fuels.** Residual bunker oil sales on the Pacific Coast are now approaching prewar quantities. Bunker oil prices at Los Angeles Harbor are lower than at most other ports and are competitive with the lowest in the world.

The ships now in operation are predominantly the American built Liberty and Victory types, which are steam-propelled and burn heavy oil. Most of the diesel ships, particularly the Japanese and Scandinavian tankers, which called at Pacific ports before the war, were sunk. New diesel ships are beginning to appear but their fuel demands are small compared to prewar.

Foreign trade is unbalanced at present, with two dollars worth of exports leaving Los Angeles Harbor for every dollar's worth of imports received. The physical volume of Pacific Coast exports, correcting for differences in price, is about 77 per cent above 1940, whereas imports are 29 per cent lower. A better balance can be expected as rehabilitation proceeds. The effect on bunker demands is likely to be upward.

● **Electric power generation.** Electric power production in the five western states during the first seven months of 1947 was 20 per cent higher than in 1946. With insufficient rainfall to operate hydroelectric plants at full capacity, more than twice as much power is being made from oil and gas this year to make up the deficiency. These relations are shown in Table 2.

The increased demand for electric power is expected to continue for several years. Even with normal rainfall, comparatively high consumption of oil and gas will be needed. Numerous hydroelectric projects are under construction or planned. The Davis dam with an installed capacity of 225,000 kw should be completed by 1950. The Grand Coulee dam is receiving three new generators this winter to increase its capacity 50 per cent. It will still have space for nine more units. The Boone-ville dam is now operating at capacity and has no room for additional units. About half the power capacity of Federal projects in the Northwest is still being used in making aluminum.

Hydroelectric generating capacity in California and Nevada will probably be 25 per cent greater in 1950 than in 1946. Steam plant capacity, including the new Redondo plant of the Edison Company and the San Joaquin Valley installations of P. G. & E. will probably be 70 per cent greater in 1950 than in 1946. This means a corresponding increase in fuel oil or gas for steam generation.

● **End of a quarter century of surplus.** As a result of all these influences the industry is now in a normal economy for the first time in a generation. The history of petroleum is one of almost continuous surplus, broken at rare intervals by a short-lived threat of shortage. Such a threat has always stimulated exploration activity and brought a flood of new oil. It can happen again. It seems like wishful thinking, but do not rule out the possibility.

In characterizing the present as a normal economy, I mean that supply is in reasonably good balance with demand and that stocks of oil above ground are not excessive. The price of crude has increased enough to compensate for the additional cost of production. The price of products has increased far less than other commodities, thus permitting customers to satisfy their desire for automobile travel, automatic heating, and many other oil benefits that they can easily afford. Employment in the industry is at record levels. Wages are good. The only thing lacking to make us feel completely at home is our usual time-honored surplus. We should learn to get along without it.

That is difficult. Nobody who has been in the oil business for less than 25 years has experienced a normal situation before. As individual operators we must know how to plan our activities for months in advance. It doesn't take much planning if every refinery has a tank farm well stocked with surplus materials. It does take planning to run every unit at full capacity and anticipate mar-

TABLE 2. Production of electric energy by public utility power plants in five Pacific Coast states, 1947 vs. 1946.

	1947—7 months		1946—7 months		Percentage increase 1947 vs. 1946
	Million kw-hr	Per cent of total	Million kw-hr	Per cent of total	
Hydroelectric	19,128	80	17,653	89	8
Steam (oil and gas)	4,772	20	2,283	11	109
Total	23,900	100	19,936	100	20

Source: Federal Power Commission.

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ket demands far enough in advance to keep product yields in balance. If that is not done, the marketing department will soon find it is short of some product or other. Nothing upsets a salesman more than to land an order and then find an empty tank when he tries to make delivery.

● **There is no oil shortage.** "But," you say, "isn't there a shortage of oil? We saw it in the headlines only a few weeks ago." I repeat, there is no real shortage of oil and there has not been a shortage of oil in California. There is no real shortage worldwide. The total supply is adequate to meet the total current demand although sometimes there is difficulty in moving the oil to the place where it is wanted. Even that kind of temporary shortage has not occurred here.

Two facts alone are sufficient to prove this point. First, total stocks of crude and products are about 91,000,000 bbl compared to 88,000,000 bbl at the beginning of the year. Present stocks are 20,000,000 bbl higher than at the end of the homeward-bound troop rush in March, 1946. At that time the industry had 75 days' supply including its working stocks. It now has 95 days'. The fuel oil inventory is now 22,000,000 bbl compared to 15,000,000 bbl on March 31, 1946, and 20,000,000 bbl on March 31, 1947. These dates mark the end of the winter heating season when fuel oil stocks are at their seasonal low point.

TABLE 3. Petroleum inventories, Pacific Coast territory. Stocks in five western states vs. current demand.

Period ending	Total petroleum (including crude oil)		Gasoline and naphtha distillates		Gas oil and diesel fuels		Residual fuels	
	Million bbl	Days' supply	Million bbl	Days' supply	Million bbl	Days' supply	Million bbl	Days' supply
1920—December 31	30.1	100						
1925—December 31	155.8	273						
1932—December 31	165.2	310						
1938—December 31	159.6	245						
1945—June 30	72.2	64	16.3	41	9.6	129	16.7	32
—December 31	73.0	79	17.6	66	8.1	82	17.8	40
1946—March 31	71.1	76	17.8	64	6.9	55	15.1	34
—June 30	78.4	91	17.2	56	8.8	104	19.7	55
—September 30	85.3	98	17.6	54	12.0	166	22.4	66
—December 31	88.5	96	19.2	63	12.4	99	22.4	61
1947—March 31	87.3	88	19.3	62	10.8	74	20.0	48
—June 30	90.4	94	18.1	51	12.8	128	21.4	58
—September 30 (est.)	91.6	94	17.7	53	14.2	151	22.7	58

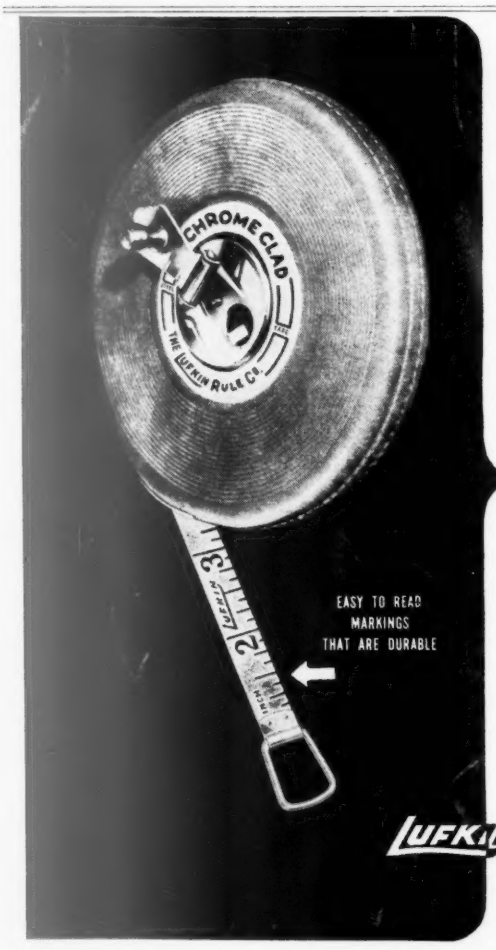
Source: U. S. Bureau of Mines.

The second proof is in the fact that during the first half of 1947 California exported an average of 81,000 bbl per day. I submit that when stocks are increasing and as much as 8 per cent of our total supply is moving offshore, there is no real shortage.

What then caused the newspaper headlines? Most of the reports, came from governmental agencies. Some were military, others were civilian, including at least one municipal agency. Practically every report followed an occasion where some agency was unable to obtain coverage under purchasing methods established by their own regulations or affected by circumstances other than oil supply. For example, the Army and Navy and most other Federal agencies cannot make contracts to purchase supplies beyond the end of their fiscal year. They must wait for new appropriations from Congress at the beginning of each new fiscal year. Immediately after July 1 they come into the market and want to purchase a whole year's supply in a matter of a few weeks. Because the seller has a hard time shifting gears this fast, there is a great deal of drum beating and flag waving for a time and then we find that one way or another the military requirements are met.

Military requirements are the most uncertain items in any forecast. This is understandable. The Army and Navy can buy in any area, have worldwide transport facilities and have the ability to store large quantities. At the end of hostilities they stopped buying some fuels entirely and drew on their own stocks. We as taxpayers have no quarrel with this. Further, since it would not be prudent for the military to make public either its operations program or its storage position, an industry forecaster has no factual basis from which to compute military predictions in advance. Military demands change suddenly and unpredictably. Time is required to work out the answers. The situation will probably improve now that central advisory committees of oil men are being organized to work with the Army and Navy Supply Board.

There were some other shortage stories that emanated from a large municipal power department. It advertised for bids to purchase a sizeable quantity of fuel oil and received no answer. I don't know why. I do know that the methods of purchasing that were effective in a buyers' market may fail to get results in a sellers' market or in a time like the present. There wasn't any shortage of oil. There was a shortage of bids. Their purchasing department quickly became aware of the changed situation, began making calls and negotiating with oil companies, and in a little while the city's requirements were covered for a safe period. The electric toasters are



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still able to burn the toast every morning.

● **Inventories.** Table 3 shows the recent trend of Pacific Coast inventories compared to prewar in terms of total barrels and days' supply. We have already seen that inventories have been rising since the war.

In our opinion the minimum stock levels for good economic operation is about 100 days' supply. This corresponds very roughly to 100,000,000 bbl at the present rate of consumption. The quantity will vary with the demand. In the correspondingly tight situation of 1920, for example, we had 100 days' supply with only 30,000,000 bbl.

This does not mean that if supplies were cut off, sales could continue for 100 days. Included in the 100,000,000 bbl are the working stocks that fill the pipe lines, the tank bottoms, the refinery units, and the vast network of transportation and distribuion facilities. Such minimum working stocks are estimated at 75,000,000 to 80,000,000 bbl. Under wartime conditions total stocks dropped a little below these figures. The difference between 75,000,000 or 80,000,000 and 100 days' requirements is needed for seasonal fluctuations and to provide some flexibility for sudden changes in demand.

● **Crude oil production forecast.** California crude oil production reached its peak about the time of the surrenders in 1945 at 942,000 bbl per day. Immediately thereafter production was cut back at the Elk Hills Naval Reserve and in other areas to about 840,000 bbl per day. Under the impetus of sustained demand and successive crude oil price increases it has built up steadily and is now about 920,000 bbl per day. If no more new wells were drilled the production from present wells would probably decline to 600,000 bbl per day in a little over four years. By drilling additional wells in areas now known to be oil-bearing, the decline can be offset in part. Sooner or later, however, the present backlog of drilling locations will be exhausted. Our industry more than any other relies on resources still to be discovered.

To forecast the rate of such discoveries is speculative and cannot be done with accuracy. We assume that discoveries and extensions will be greater in the next five years than in the last five years of wartime restrictions and material shortages. We estimate that production will continue to increase a little for a period of six to twelve months more, reaching a peak of 930,000 to 940,000 bbl per day some time next year.

A peak seems inevitable because the backlog of locations is being drilled up at a faster rate than new locations are being found. If no large discoveries are made to change the trend, production may decline to 800,000 bbl per day by the end of 1950 and 750,000 bbl per day by the end of 1951. In this event California must seek about 100,000 bbl per day in 1951 from sources not now foreseen. This does not mean a future "shortage" of any such proportions. It is a measure of the task yet to be accomplished. We are confident that the requirements will be met as they arise. A job like this will take time and a great deal of money but it will not require any magic nor any skill which the industry has not already demonstrated.

● **Crude oil reserves.** There are many conflicting conclusions regarding the crude oil reserves of California and other areas. This is a strange situation. It demonstrates a lack of understanding because there is only one set of statistical data on reserves and there is no quarrel with the figures. Some published stories say less oil is being discovered than is currently being produced; other stories say our proved reserves are increasing each year. How can such obviously inconsistent statements be drawn from a single set of uncontested figures?

As I read the figures the estimated proved reserves of crude oil in California at the beginning of 1947 were 3,300,000,000 bbl. This is a little less than the 3,400,000,000 at the end of 1945 and a little greater than the 3,000,000,000 at the beginning of 1937, ten years ago. Throughout the ten-year period the reserves have fluctuated within a very narrow range with an overall tendency to increase more than to decrease.

In the ten year period 1937-1946 new discoveries and other additions to proved reserves totaled 3,000,000,000 bbl, which equals the total amount existing at the beginning of the period. Offsetting the discoveries we find a ten-year production totaling 2,700,000,000 bbl. Thus there was a net increase over and above production amounting to 300,000,000 bbl. In other words, production withdrawals amounted to nearly the entire reserve that existed at the beginning of the period and yet new discoveries and additions were sufficient to end the period with 10 per cent more proved reserves than at the beginning. The facts are that additions to reserves have more than kept pace with production, even though not one major field was discovered in the entire ten years.

The figures that some writers quote to show that discoveries are lagging far behind production are fragmentary figures that result from the technical bookkeeping methods established by the committee on reserves. There is nothing wrong with the system. We need only to understand it.

The reserve figures each year show the amount added to reserves during the year in two separate items or columns. One is headed "Discoveries." This includes only the estimated reserves discovered during the current calendar year and credited at the end of the year in fields or zones that were unknown before that year. The other item or column is headed "Extensions and Revisions." It is really made up of two separate items. By "extensions" is meant the additional reserves credited by extending the area of fields discovered in previous years. By "revisions" is meant the change in previous estimates that has become necessary as more information concerning a field becomes known. For example, there may be only five wells in a new field at the beginning of the year. The engineers estimate the thickness, porosity, permeability, and area of the pool from the well data of these five wells. By the end of the year there may be 25 wells. An entirely new estimate is made on the basis of all the information then known. Even though the area of the field is no different, its computed volume of reserves may be more or less than the previous computation. The change is therefore entered as a revision.

It does not matter in the end whether a barrel of new reserves is listed as a discovery or as an extension or as a revision. All that really matters is the total reserve on a given date regardless of the statistical procedure by which it was obtained.

In the last ten years only 14 per cent of the additions to reserves have been listed as "discoveries." This is not surprising when we remember that such items are limited by definitions to fields discovered within the current year. Any additional discoveries in those same fields in later years are not listed as discoveries, but as extensions or revisions. The development of an oil field

TABLE 4. Estimated crude oil reserves—California. Condensate included through 1945. Shown separately in 1946. Million barrels—42 gal.

	Estimated proved reserves January 1	Discoveries of new pools this year	Extensions and revisions this year	Total additions to proved reserves this year, cols. 2 and 3	Production this year (USBM)	Estimated proved reserves December 31
1937	2956	51	295	346	239	3063
1938	3063	135	240	375	250	3189
1939	3189	47	521	568	224	3532
1940	3532		(17)	(17)	224	3291
1941	3291	19	243	262	230	3323
1942	3323	5	116	121	248	3196
1943	3196	16	409	425	284	3337
1944	3337	77	243	320	312	3345
1945	3345	63	329	392	327	3410
1946—Crude oil	3318	14	277	291	315	3294
1946—Condensate	92		(50)	(50)	2	40
1946—Total 1946	3410	14	227	241	317	3334
Ten years 1937-1946	2956	427 (14%)	2606 (86%)	3033 (100%)	2655	3334

Source: A.P.I.

always requires more than one year.

If discoveries continue to be made at a rate equal to 10-15 per cent of current production, and if these discoveries are followed by a normal expectation of extensions and revisions, reserves will continue to be kept in balance.

Another story may help to clarify the difference between discoveries and extensions. The amount of oil listed in the discovery column may be quite different for a field discovered in January than for the same field if it had been discovered in December. This is because a different amount of time would elapse before the end of the calendar year and any additions beyond the end of the year of discovery would be listed under extensions. Think for a moment of Wilmington, which our company discovered late in 1936. When the reserve estimates were made at the end of the year there was only one well on production. It would be unusual if the reserve committee credited a single well with more than 100,000 or possibly 200,000 bbl of reserves. This was probably all the oil ever listed in the discovery column for the earliest zone of the great Wilmington field. Millions of additional barrels were listed as extensions in 1937 and later. If the field had not come in until January, 1937, millions of barrels would have been credited as discoveries by the end of 1937. So you see it makes little difference in which particular column the reserves are entered. The *total* addition to reserves is the only figure that should be compared with production. People unfamiliar with these technicalities continually make the mistake of reading only the discovery column. These are the people who conclude that we are fast running out of oil because we are producing many times as fast as we are "discovering" new oil. I hope you will examine Table 4. See how easily such an inference can mislead the uninitiated.

● **Higher costs of replacing reserves.** The accomplishment of the industry in maintaining its reserve position is great. We can be proud of it, however, let us not think the job is an easy one. The effort required is increasing by leaps and bounds. Although the results add up to a satisfactory total, it is barely satisfactory and is actually disappointing if we think of it in terms of the effort and in terms of the results of past decades.

It seems that the easy discoveries have already been made. Surface geology has discovered the continent. Geophysical methods have carried the search to great depths. From here on the task of finding oil will become more and more difficult and more costly.

In 1937 the cost of replacing a barrel of crude oil with a newly discovered barrel averaged 27 cents, according to Mr. Pogue of the Chase National Bank, an authority on oil finance. By 1945 the replacement cost was 72 cents. Current estimates would be still higher. But even today's costs will not deter the industry in its search for reserves so long as there is opportunity for profit. The surest way to obtain more oil is to make it worth while for somebody to hunt for it.

● **Possibilities for the immediate future.** What are the most likely ways to continue the replacement of production with new reserves? First of all, the presently known areas are under vigorous development. Even if "discoveries" should stop entirely, "extensions" would continue for some years. These normally add six additional barrels to every first-year discovery barrel, but even this would become only a bone-picking operation if there were no further exploration.

Exploration is currently proceeding at a very high rate. Mr. Collom's recent paper indicates that the number of exploration geologists in California has doubled in the last ten years.

In spite of increased costs and other difficulties that increase the risk of wildcatting, exploration will continue until we run out of places to search. This is still many years away. All presently known oil reserves in the United States are contained in about 8000 sq mi of area. This is only one-half of one per cent of the continental land area. Even in California there are still places to look, although most of the area has been looked at more than once. There are undoubtedly many millions of barrels that have eluded surface geology and geophysics. Such fields as Coalinga Nose were not found and cannot be

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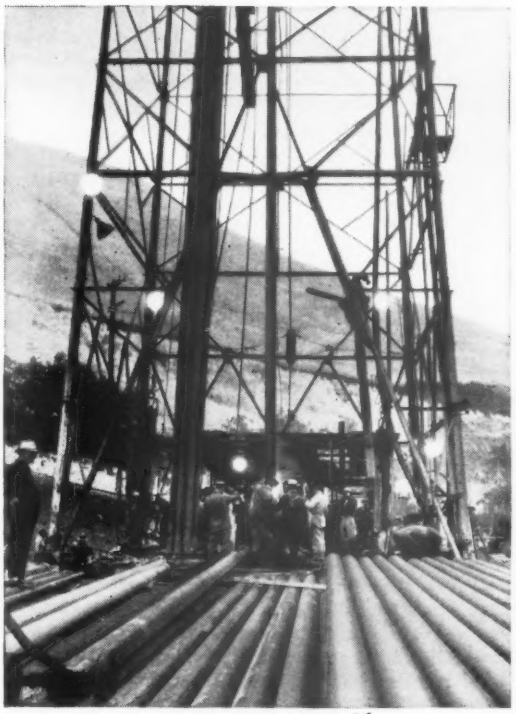

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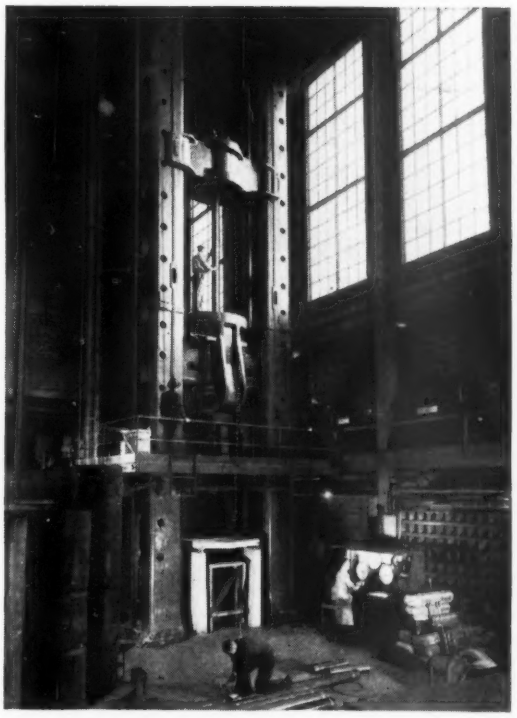

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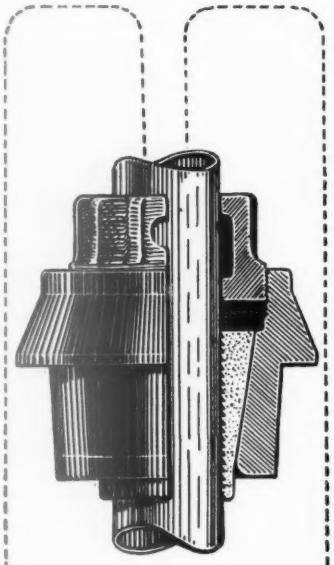

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found by such methods. The constant development of new techniques for geological analysis of stratigraphic and lithologic traps is likely to ferret out more fields like this and many other smaller ones.

The present price levels are also making it possible to repair old wells and to extend the margins of various old fields where the production is small but still able to pay out. We must remember that the "edge" of an oil field is not necessarily a margin beyond which there is no oil. It is the margin beyond which production cannot pay its way, like the margin between high grade and low grade ore.

● **Large backlog of hitherto "unrecoverable" oil.** The largest potential reserve that commands attention now is already blocked out but has never been listed as a discovery or included in the *proved* reserves in any way. I refer to the portion of the crude oil that is unrecoverable by any present methods. Most experts say only 35 per cent or so of the volume in the underground reservoir can now be considered recoverable. The reserve figures include only this portion. They do not include the other 65 per cent. For every barrel produced to date or remaining in the "proved" reserves, there are two or three barrels blocked out and lying in place, waiting only a knowledge of how to recover them. This enormous backlog of potential oil challenges the ingenuity of the engineers and chemists. Your kind of technology can be effective here, without asking the geologists to carry the whole problem for the future. It is just as effective to find new reserves by increasing the percentage recovery in old reservoirs as it is to find new oil. In fact, it is more effective, because better recovery will also increase the reserves that become available by discovering new pools.

The trend in this direction is encouraging, particularly in California. There is a rapidly increasing realization out here of the importance of unit operations and pressure maintenance programs.

The heart of such programs is the proper utilization of natural gas for reservoir control to obtain maximum ultimate recovery of total energy in all forms.

The primary function of natural gas is to produce as much *liquid* petroleum as possible. It should not be used for any other purpose until it has accomplished this purpose fully.

The use of gas for repressuring and cycling does not *consume* gas. It *conserves* gas and increases the ultimate hydrocarbon recovery from the reservoir.

Other methods, all grouped under the term "secondary recovery" have also been under increasingly vigorous development in the last decade or two. Water drive and chemicals are being employed in the East. Dewatering of flooded fields in Kern County has increased the oil production there by pumping very large quantities of water. This costs money, but the point is that more oil is being obtained from fields that were pretty well depleted by earlier methods.

Methods that remain for the more distant future include mining, horizontal drilling, and even the use of bacteria.

Secondary recovery methods are likely to require legislation to apportion the benefits and the costs fairly and to prevent some selfish operator from participating in the benefits without sharing the burdens.

As oil and gas are irreplaceable resources, we cannot count on using them forever. What kind of a transition is likely to occur as current supplies dwindle below current needs?

There is no likelihood of a dying-off process whereby the petroleum industry will be replaced by some competing industry that finally will become supreme. Our true relationship to the industry of the future foretells quite another trend.

The present liquid fuel industry has long since ceased to be a servant of crude oil, existing only for the utilization of one kind of natural resource. It is rather the servant of the machines that consume the fuels. We are manufacturers of liquid fuels, not merely "refiners" of crude oil and natural gasoline. We shall make the kind of fuels needed for the engines of the future and in the quantity needed without much regard to the source or nature of the raw material. Assuming free competion between materials, we shall use the cheapest material that will accomplish the job. The economics of the market place will dictate the course of the future just as it has in the past.

The processes of the future are almost certain to remain in the hands of our own chemical engineers and their successors. The greatest resource of the American fuel industries is their engineering and technical skills. Even the technical knowledge of today is sufficient, without any more developments, to provide our energy needs for many generations with materials already blocked out.

But research has not stopped. In fact, the magnitude of the research investment is the most convincing proof that oil technology will not be superseded by coal. The petroleum industry spends 40 cents per ton of its product for research, excluding exploration research. The coal industry is reported to be spending 0.4 cent per ton. Which is likely to have the greatest reserve of technology ten years hence?

Long before petroleum is exhausted, it will be supplemented by liquid fuels from other source materials. Oil will be produced much longer than the ten or twelve years computed from present reserves divided by current demand, but substitution from other sources is likely to begin in some areas before that period is up.

What is to be the next source? The present lineup seems to be natural gas, coal, and oil shale, in that order. Natural gas is soon to be liquefied on a commercial scale in the Mid-Continent and Gulf areas. This is not applicable

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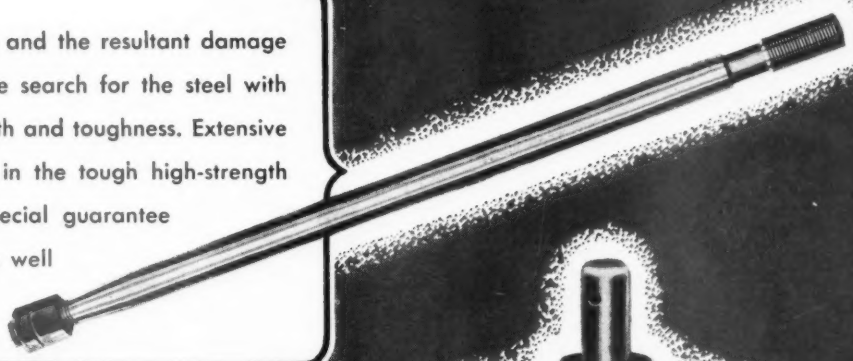

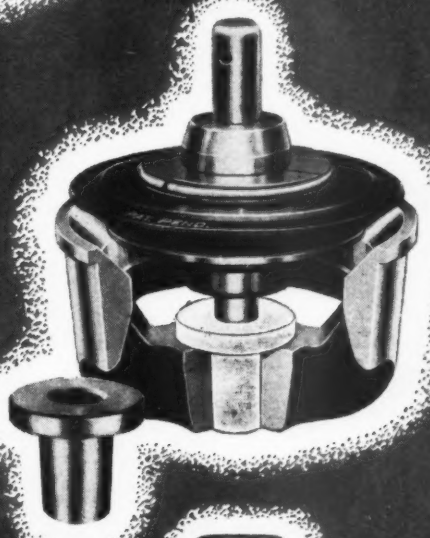

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in California because we are about to import gas itself. We have no surplus available. Next in line, coal is the most favored by eastern engineers. Processes developed in Europe and improved in the United States since the war offer to supplement petroleum in the near future at costs that are not prohibitive although they are not competitive. Many problems are yet to be solved before we enter upon the thousand-year period of coal technology assured by present coal reserves. Oil shale is of little current interest here. It is, however, providing fuel in Scotland and Sweden.

There isn't much comfort for California fuel manufacturers in a future dependent on coal. There are no important reserves of coal in this state, although there are some small deposits that have been produced for many years in the past. There are larger deposits of low-grade coal in the Northwest. To find really important deposits we must look to Utah and other Rocky Mountain areas or to imports. There isn't likely to be any payout for liquid fuel made from coal imported into California. The coal processing plants should be located at the coal mine and the products moved by pipe line. Best of all would be a successful method of burning the coal in place by injecting oxygen under control, thus manufacturing carbon monoxide or water gas, which could be enriched and piped to industrial areas. All such attempts have failed so far because the heating value of the gas obtained was too low.

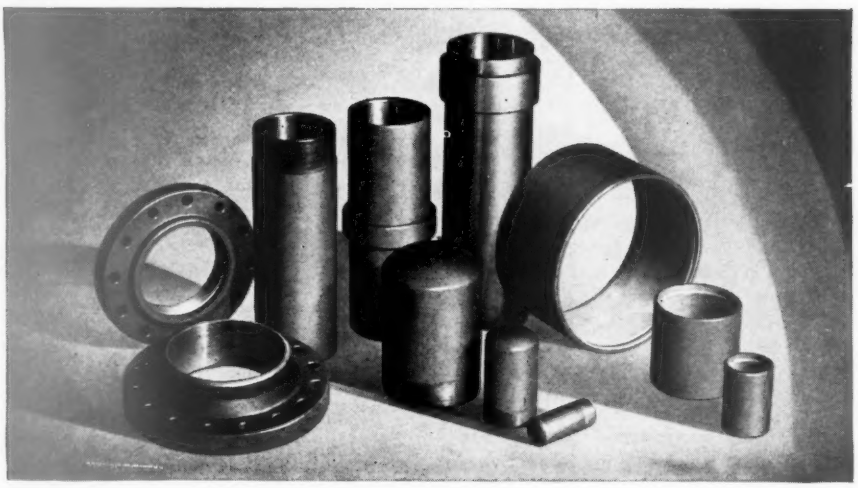
● **Imports.** If we must expect to import some of our energy in the future, we may as well stick to oil and gas. This appears more feasible, anticipating that supplies can be drawn in the future from the Rocky Mountain area, still comparatively untested, from West Texas, or from foreign fields that have been developed by American companies. The present surplus areas for crude oil include West Texas, the Caribbean, and the Middle East. Oil from any of these areas could be brought to California without prohibitive cost. Any of these movements would require large amounts of capital and would not be attempted on a fly-by-night basis. As local producers would already be selling all their oil, they would not be harmed. We do not foresee now that any such importation is likely to be needed before 1951, and many things can happen to improve our local situation before then. The only point to remember is that importation is not likely to begin before it is needed, and then it will have no bad effects.

● **Summary.** The pyramiding effects of the war, population growth, greatly increased per capita consumption of energy, and limited rainfall have carried the Pacific Coast petroleum industry out of its surplus era into a normal economy for the first time in a generation. There is no real shortage here and none is in sight. Rumors to the contrary arise from purchasers who are not aware of the shift from a buyers' to a sellers' market. Oil is not overly plentiful, however, and careful planning is needed to avoid local dislocations and to provide military requirements.

Petroleum inventories have increased substantially since the war but are still below the minimum economic level of 100 days recommended. Exports in the first half of 1947 were 81,000 bbl per day, or about 8 per cent of the total supply. Crude oil reserves have been maintained at levels sufficient to balance withdrawals for the last ten years although not one major field has been discovered in that time. Reserves are likely to be ample for many years to come.

Crude oil production is expected to increase from the present 920,000 bbl per day rate to a peak of 930-940,000 bbl per day some time in 1948. Thereafter it is likely to decline because the present backlog of locations is being drilled up faster than new locations are being discovered. By 1951 we shall need 100,000 bbl per day more than the production rate that can now be foreseen.

Future possibilities that may appear include the discovery of many elusive fields of the Coalinga Nose type, unresponsive to geophysics and surface geology; better recovery methods from old fields; imports, and finally, partial substitution of other source materials. No need for crude oil imports is now foreseen before 1951. The circumstances under which they would become necessary are not likely to harm California producers. ★ ★ ★



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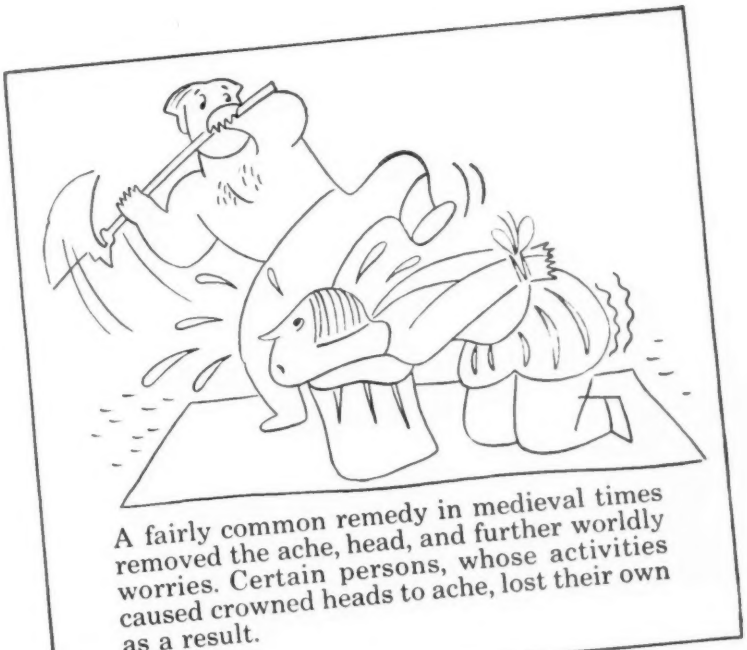
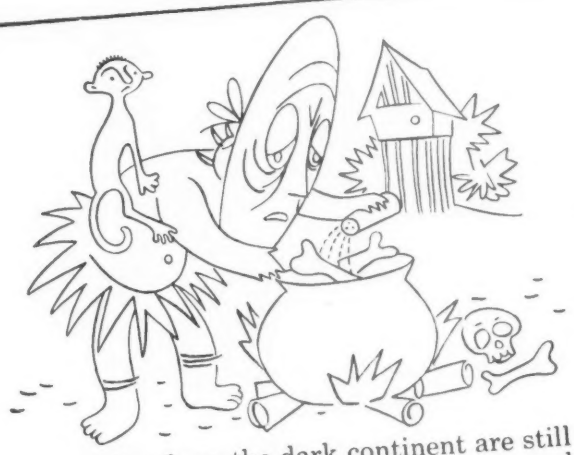


A fairly common remedy in medieval times removed the ache, head, and further worldly worries. Certain persons, whose activities caused crowned heads to ache, lost their own as a result.



Remedies from the dark continent are still being brewed daily from bat brains and orchid petals. In case of an ineffectual batch, the kettle is still handy for an extended liquid hot-foot.

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Metallurgical properties of high yield strength seamless line pipe*

By A. B. WILDER[1] and J. D. TYSON[2]

● **Introduction.** Long distance transportation of petroleum, petroleum products, and particularly natural gas, has in recent years created a vast network of pipe lines, which are the connecting links between our natural resources and the industrial centers of population. In the relatively near future, a probable additional demand for pipe lines will originate with the production of gas from coal. Although fluids have been conveyed over long distances for hundreds of years, the large transmission pipe line is the creation of modern civilization, and we are now embarking on a period of its greatest usefulness.

Steel has been almost universally used for pipe line construction and one of the most important developments in the application of this material has been the field welding of joints. It is the generally accepted practice to weld line pipe without preheat, a postheat, or the use of a back-up strip. Such practice, however, requires a proper steel and welding technique. After the pipe has been welded, it is frequently coated with a bitumastic or other material to prevent soil corrosion. Anodic protection of the pipe may also be used to inhibit corrosion. A special corrosion resistant steel, therefore, is not required in pipe line construction as other methods have been developed for protecting the outside and inside surfaces of the pipe.

In addition to providing a suitable material for welding, it is also important to consider the tensile properties of the steel. A problem of this type involves a consideration of the yield strength of the material, which has an important economic bearing not only in the design of the pipe line, but also in the manufacture of the material. A high yield strength steel not only permits the use of lighter wall pipe, but also higher working pressures. If an expensive alloy steel is used to obtain higher physical properties, then the economic advantages of the material may be lost. Further, the yield strength is limited by welding requirements. Therefore, in providing a high yield strength material, the manufacturer must either utilize the full benefits to be derived from the addition of suitable chemical elements to the steel or resort to other methods for improving this property.

Under suitable welding conditions, it has recently been developed that steel melted to 0.40 max carbon and 1.40 max manganese with a minimum yield strength of 52,000 psi may be used for pipe lines. A steel of this type may be economically produced in large diameter seamless pipe. This should be compared with steel melted to 0.30 max carbon and 1.25 max manganese with a minimum yield strength of 42,000 psi, which is commonly used for line pipe. Naturally, a steel with higher chemistry requires a different welding technique, but a steel of this type provides a joint that possesses inherent physical properties after welding that are closely related to the chemistry of the original material.

Pipe for oil or gas transmission lines is often machined on the ends with a 30-deg bevel and a 1/16-in. face. Joints are usually lined up, and tack welded, but if an internal line-up clamp is used, the necessity of tack welding is eliminated. In the manual metallic arc welding of light wall line pipe, usually a root bead, one or two filler beads, and a cover bead are used. Defects in a weld of this type are usually localized and, therefore, the strength of the joint is maintained. All-position welding is frequently used, and multiple passes have the effect of heat-treating the deposited metal except for the last pass, which is the cover bead. When pipe bends in the line are required, the main body of the pipe may be hot or cold bent so that the weld is not subjected to this treatment. In this investigation, manual metallic arc welding was employed, although other types of welding have been used in the field. Due to the fact that only seamless pipe was considered, the problems encountered in girth welding were studied.

● **Purpose of investigation.** This investigation involves a study of the properties of a new grade of seamless line pipe with a 52,000 psi minimum yield strength and 75,000 psi minimum tensile strength. In the manufacture of the seamless pipe, the approach to these requirements involved the use of carbon and manganese. Due to the fact that current practice in the manufacture of seamless line pipe has been limited to 0.30 max carbon, 1.25 max manganese with a minimum yield strength of 42,000-45,000 psi (depending on the wall thickness), the application of seamless pipe with a minimum yield strength of 52,000 psi involves a number of problems due to appreciable increase in strength characteristics.

Upon the basis of extensive experience in the production of seamless cas-

TABLE 1. Chemical and physical properties of the steel tested.

Code no.	Type	Process	C	Mn	P	S	Si	Yield 1000 psi	Ultimate 1000 psi	Per cent elongation in 2 in.
A	26″ OD x 0.303″ wall pipe..	O.H.	0.36-0.39	1.24-1.28	0.014	0.033	..	55-69	86-100	27-35
B	18″ OD x 0.312″ wall pipe..	O.H.	0.38	1.42	0.010	0.023	0.24	65	98	28
C	20″ OD x 0.312″ wall pipe..	O.H.	0.22	0.47	0.008	0.022	..	43	64	42
D	26″ OD x 0.303″ wall pipe..	O.H.	0.30	1.12	0.011	0.023	..			
E	26″ OD x 0.303″ wall pipe..	O.H.	0.31	1.26	0.011	0.022	..			
F	26″ OD x 0.303″ wall pipe..	O.H.	0.36	1.14	0.009	0.021	..			
G	26″ OD x 0.303″ wall pipe..	O.H.	0.37	1.36	0.010	0.026	..			
H	0.303″ gage plate.....	I.F.	0.32	1.35	0.016	0.027	0.08			
I	0.303″ gage plate.....	I.F.	0.37	1.37	0.016	0.027	0.08			
J	0.303″ gage plate.....	I.F.	0.41	1.16	0.015	0.026	0.05			
K	0.303″ gage plate.....	I.F.	0.40	1.34	0.016	0.025	0.07			
L	0.303″ gage plate.....	I.F.	0.40	1.42	0.011	0.019	0.09			

O.H.—Basic Open Hearth. I.F.—Induction Furnace.

TABLE 2. Chemical and physical properties of the weld metal.

Electrode	Typical analysis of deposited metal								Yield 1000 psi	Ultimate psi	Per cent elongation in 2 in.
	C	Mn	Si	P	S	Mo	V	Cr			
(U) E-6010	0.10-0.14	0.40-0.55	0.01*	0.030*	0.035*	..	..	..	53-60	65-77	22-30
(V_1) E-7010	0.09-0.13	0.50-0.65	0.10	0.035*	0.035*	0.50-0.55	..	..	62-66	77-82	18-25
(V_2) E-7010	0.08	0.70	0.28	0.019	0.015	0.48	..	..	62-70	73-85	20-25
(V_3) E-7010	0.07	0.34	0.15	0.017	0.022	0.52	..	..	57-63	72-80	25-28
(W) E-8011	0.11	0.34	0.19	0.012	..	0.52	..	0.54	73-75	88-90	19-20
(X) E-10010	0.09-0.13	0.50-0.65	0.10	..	..	0.70-0.85	0.10-0.15	..	90-100	103-112	14-17

*Maximum.

*Presented before the American Welding Society, Chicago, Illinois, October 18-24 and published in *Welding Journal*.

1. Chief Metallurgist, National Tube Company.
2. Chief Metallurgist, Lorain (Ohio) Works, National Tube Company, subsidiary of United States Steel Corporation.

ing with a minimum yield strength of 55,000 psi, it was concluded that the physical property requirements of the new grade of seamless line pipe could be obtained by melting steel to 0.40 max carbon, 1.40 max manganese. Steel of this type was successfully rolled into 26-in. diam seamless pipe and satisfactory tensile properties were obtained. An evaluation of the metallurgical properties of the material remained to be determined and it is only this phase of the work that will be discussed. Although other interesting problems were encountered in the manufacture of this new grade of steel, the user is primarily interested in the properties of the material, particularly regarding welding.

In order to develop metallurgical information concerning the behavior of the new material under welding conditions, the influence of welding technique was explored. This involved a study of various types of weld rod combinations and weld bead sequence in girth welds. A range of chemistry was explored. In addition, tensile tests, bend tests, microstructure, hardness surveys, X-ray examinations, and weld bead tests were studied.

● **Materials.** The chemical and physical properties of the various steels used in this investigation and the type of material tested are shown in Table 1. Chemical and physical properties of the weld metal in the as-welded condition are shown in Table 2. Electrodes V_1, V_2, and V_3, although of the same type, were of different manufacture. All open hearth steels were tested in the as-rolled condition and the induction furnace heats were normalized.

The chemical and physical properties of approximately 350-160-ton heats of steel, which have been rolled into 26-in. OD by 0.303-in. wall line pipe, are as follows:

	Specification	Actual range
Carbon	0.40% max.	0.30-0.39%
Manganese	1.40% max.	0.94-1.36%
Phosphorus	0.040% max.	0.007-0.027%
Sulphur	0.050% max.	0.017-0.047%
Alloys		Residual
Yield strength (psi)	52,000 min.	53,500-74,000
Ultimate strength (psi)	75,000 min.	79,400-100,000
Elongation in 2 in.	22%	22.5-38.0%

The 26-in. OD by 0.303-in. wall line pipe used in this investigation was selected from the above heats. The other types of material tested were melted on the basis of chemistry, as all of the regular production heats had not been melted at the time of the experimental program.

● **Testing methods.** *Girth welds.* Circumferential welding of full pipe sections was used in this investigation. The pipe was rotated and manual metallic arc welded with coated electrodes in a down hand position. After tack welding, a root or stringer bead was applied, followed by a filler bead and finally a face or cover bead. The type of joint and welding sequence is shown in Fig. 1. Possible modifications of the welding sequence described in Fig. 1 are indicated elsewhere in this investigation. Except where noted, the girth welds were not preheated, postheated, or stress relieved.

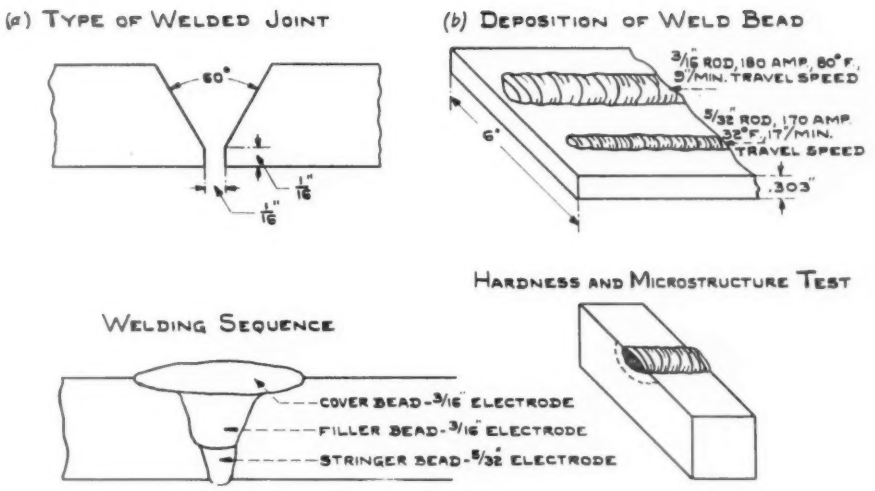

FIG. 1. Type of welded joints and weld bead tests used in investigation.

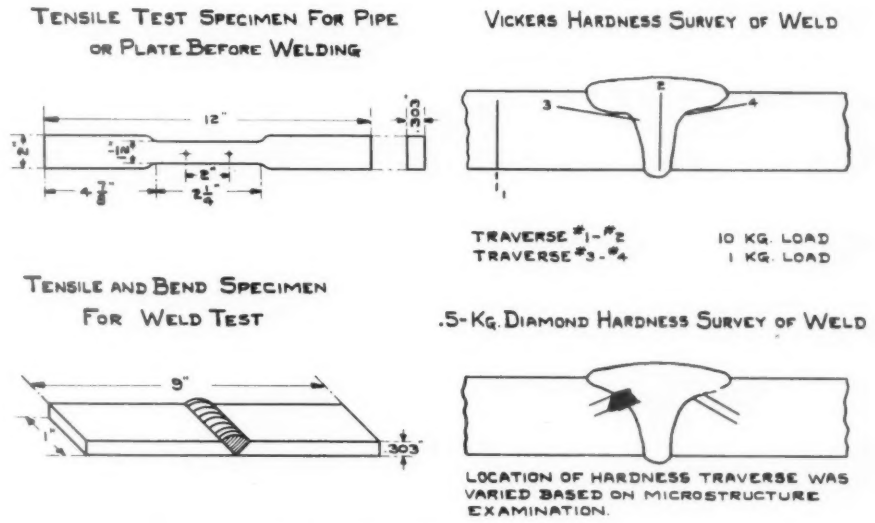

FIG. 2. Tensile, bend, and hardness test specimens.

Weld bead tests. In order to reduce the variables associated with manual metallic arc welding, weld bead tests shown in Fig. 1 were made at the U. S. Steel Corporation Research Laboratory. These beads were deposited with an automatic welding head with a stick electrode attachment. As may be noted from Fig. 1, two single weld beads were deposited on each steel specimen. One bead, 6 in. in length, was deposited using a 3/16-in. diam electrode with 180 amp and 9 in. per min travel speed. The plate was at 80 F prior to deposition of this bead. A second bead, 3 in. in length, was deposited using a 5/32-in. diam electrode with 170 amp and 17 in. per min travel speed. The plate was cooled to 32 F prior to deposition of this bead. The reason for depositing two beads of such widely different characteristics was to represent (1) normal or average welding practice and (2) the most unfavorable welding conditions that might be encountered, particularly in tack welding. An E-7010 welding rod was used for both beads. A transverse section of the weld bead test was examined and the micro-structure and hardness evaluated. A longitudinal section of pipe was also used so that the beads would be deposited under conditions similar to the plate specimens.

Tensile and bend tests. Tensile tests of the original pipe and plate material were conducted in accordance with Specification API 5-L. The tensile test specimen for unwelded pipe or plate is shown in Fig. 2. Tensile test specimens of welded pipe sections are also shown in Fig. 2 and, except where noted in the investigation, excess weld metal was not machined from the specimen. Although tensile test strip specimens from welded pipe are usually prepared by oxyacetylene flame cutting, in this investigation the specimens were machined from the pipe.

A guided bend test with a 5/8-in. radius plunger was used. Except where noted in the investigation, the guided bend test specimens were similar to the tensile test specimens of the welded pipe sections shown in Fig. 2. In the bend test, pressure was applied in a tensile testing machine until a crack appeared

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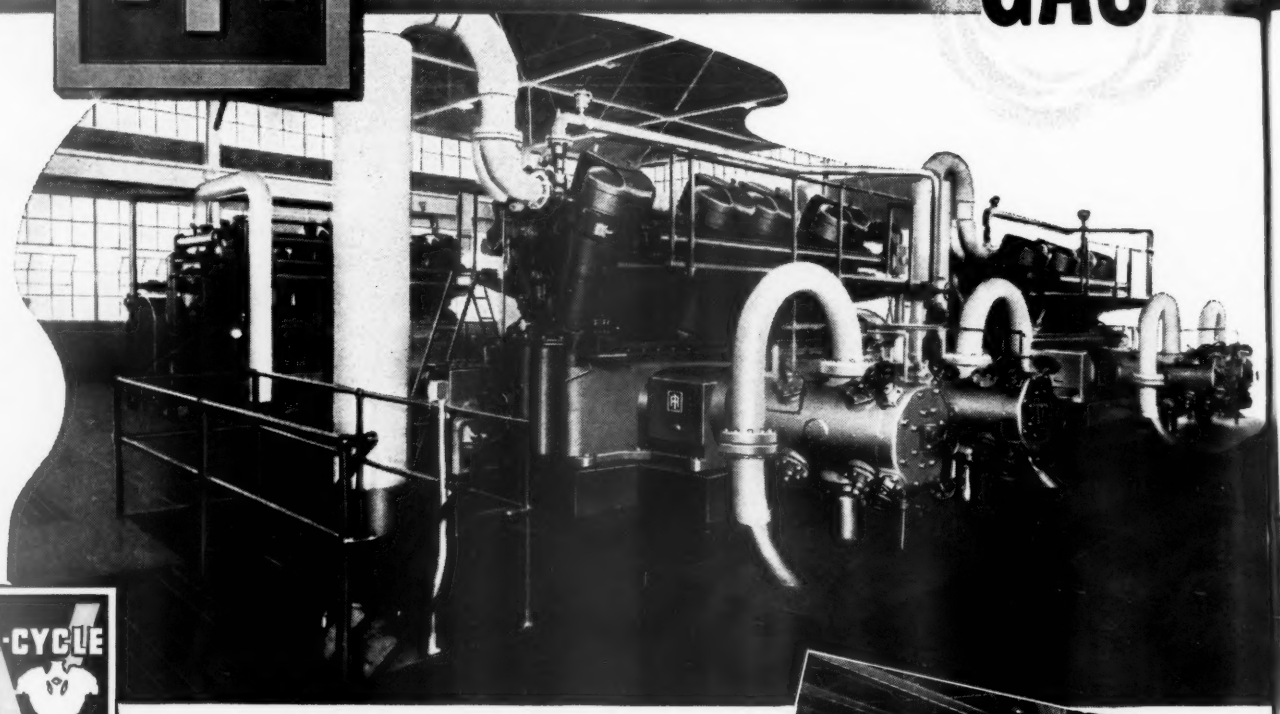

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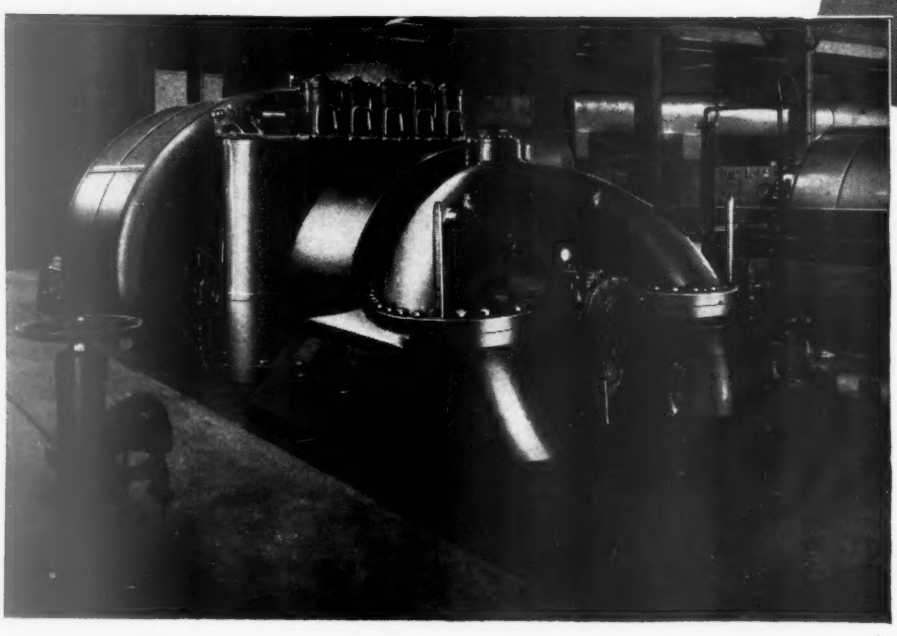

(Above) 275-hp Type PVG 4-cycle gas-engine generator units.

(Left) Typical I-R Turbo-Compressor with steam-turbine-drive.

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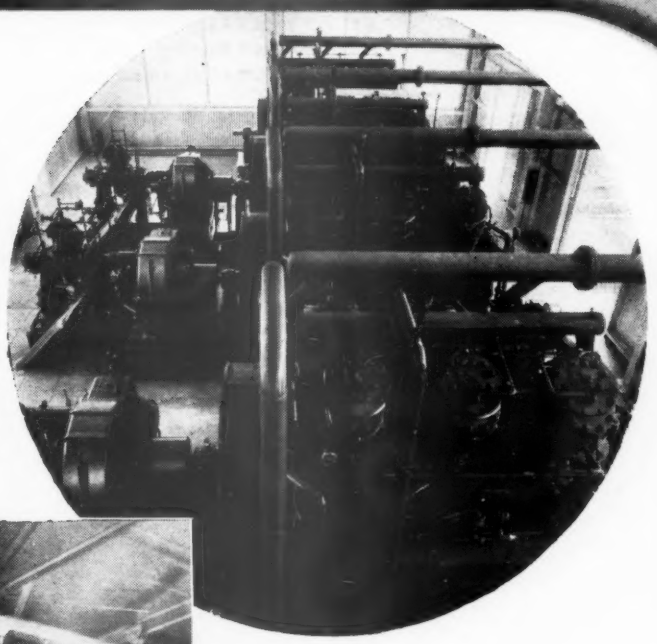

(Right) These Class RT Pipe-Line Pumps and 275-hp Type PVG 4-cycle gas engines are engineered and matched to assure trouble-free operation.

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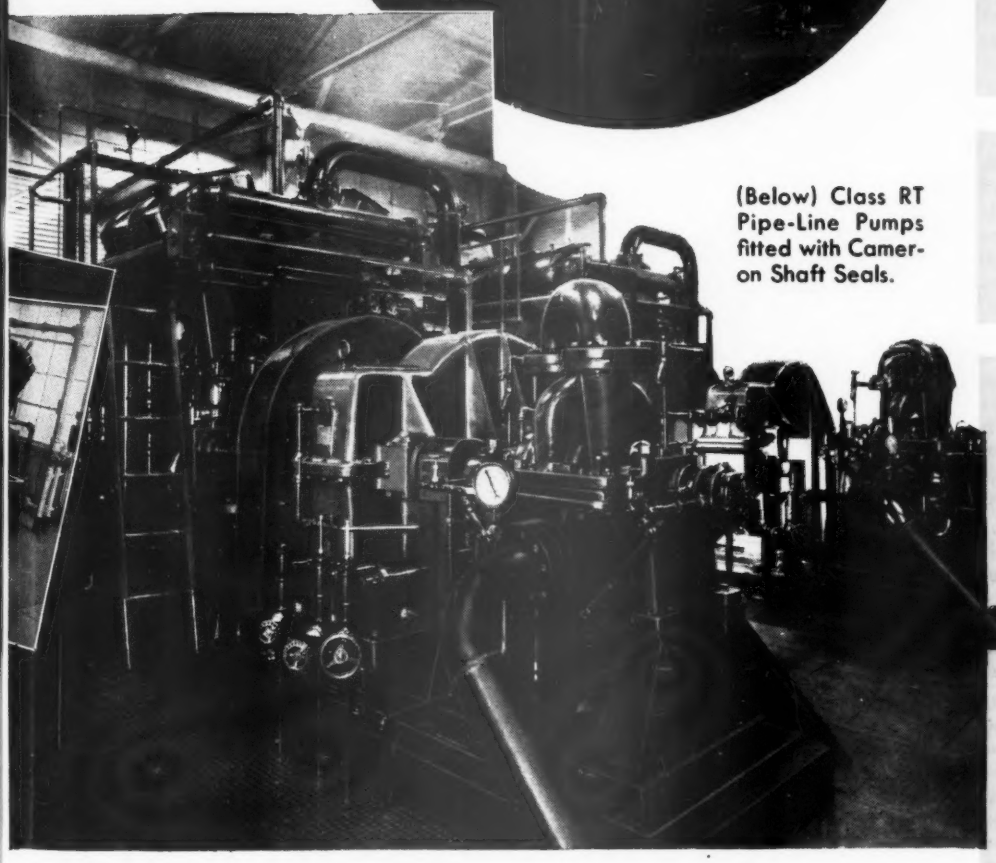

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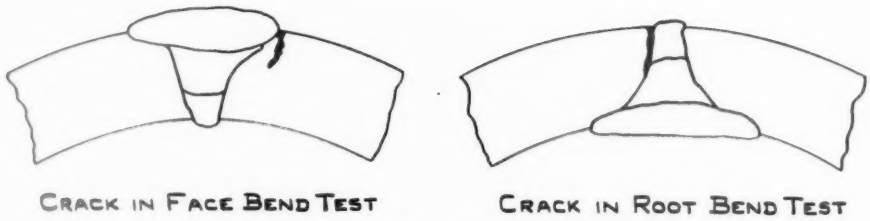

FIG. 3. Typical failures in bend tests.

or until completion of a 180-deg bend. As the 5/8-in. radius plunger was smaller than the AWS standard 3/4-in. radius plunger, the bends made in these experiments can be considered more severe than the standard guided bend test. Although the influence of aging on bend test results is frequently considered significant, this factor was not evaluated.

Hardness tests. The Vickers hardness tests were conducted with a 1 and 10 kg load on a standard Vickers hardness tester. Caution was exercised in applying a suitable load during testing because of inertia effects in the machine. In addition to these tests, hardness determinations with a 0.5 kg load were made by the U. S. Steel Corporation Research Laboratory. A transverse test specimen selected from the weld was polished for hardness testing. The specimen was machined from the welded pipe or plate section so as to eliminate any effects from heating. The locality of hardness surveys is shown in Fig. 2.

In determining the maximum hardness of weld, considerable care must be exercised to obtain satisfactory results. The U. S. Steel Corporation Research Laboratory developed the 0.5 kg load hardness testing machine used in this investigation. This machine, referred to as "Intermediate DPH Tester," comprises an indenting mechanism, a mechanical stage for holding the specimen, a microscope for locating the test field and measuring the impression, and a control box for automatically spacing the impressions. The reading error in the range of hardness investigated with a 0.5 kg load is less than 1 per cent. The error in hardness number for this reading error is not more than ± 2 per cent.

Other tests. X-ray examination of welded pipe joints was conducted with a 185,000-volt X-ray machine and radiographs of the complete welds were made. Any indications in the radiographs of cracks or other defects in the weld were confirmed by metallographic examination.

Metallographic examination of the weld heat-affected zone base metal and the base plate was conducted on a transverse weld section which was also used for hardness testing. Weld specimens were machined from the pipe in order to eliminate the possible effect of flame cutting.

● **Bend test technique.** In welding pipe lines, the bend test is frequently used for qualification of welders and as a control test. The welders must be familiar with proper adjustment of welding current, obtain proper penetration, and control other factors in order to achieve satisfactory results. Although a guided 180-deg bend over a 3/4-in. radius is the standard test and is frequently considered a satisfactory qualification or control test for line pipe welders, it has not been shown that a bend of this severity is necessary for line pipe service.

A weldment of 52,000 psi minimum yield strength material should not be expected to have the same bending properties as a weldment of 35,000 psi minimum yield strength material due to the difference in minimum elongation. In addition to its intended function of indicating the defects that may be present in the weld, the bend test is to a great extent a measure of the ductile properties of the weldment at the outer fibers of the bend. It can be recognized, therefore, that the conventional bend test for low yield strength material is not truly applicable to sound welds of high yield strength material. If a test of this type is to be applicable for all types of welded line pipe joints, there should be some modification that more clearly recognizes varying levels of ductility, depending upon the strength of the material tested. It is believed that a practical approach to such a modification would be to vary the radius of the bend test so that the maximum elongation in making a 180-deg bend would be proportional to the expected elongation of the material welded. In the standard bend test, the types of failures usually encountered are shown in Fig. 3.

The cover bead in the tensile test of line pipe welds reinforces the weld and strengthens the heat-affected zone, but is detrimental in the bend test, due to stress concentration associated with the notch effect. Lack of proper penetration or excess weld metal in root bead also develops a notch effect that is harmful. In order to evaluate this situation, a number of special bend tests were performed.

In Table 3, bend and tensile test results obtained with various types of specimens in 26 in. OD by 0.303-in. wall high yield strength pipe and 20-in. OD by 0.312-in. wall, 35,000 psi minimum yield strength pipe are summarized. The procedure for making the bend tests have been described previously. In the face bend test of high yield strength pipe, grinding the cover bead to eliminate notches improved the results. Grinding the root bead is beneficial in the root bend test if a notch is present. In the root bend, grinding of the cover bead decreased the reinforcing effect

TABLE 3. Bend and tensile test results of welded pipe.

Treatment	Weld rod	Face bend		Root bend		Tensile		
		No. of bends	Angle	No. of bends	Angle	Yield 1000 psi	Ultimate 1000 psi	Per cent elongation in 2 in.
26 in. OD x 0.303" wall (0.36-0.39 per cent carbon, 1.24-1.28 per cent manganese steel)								
Unground	*	6	135°	6	160°	68	91	22
Cover bead ground flush	*	6	170°					
Root bead ground flush	*			6	175°			
Cover bead and root bead ground flush	*	3	180°	3	140°			
20-in. OD x 0.312" wall (0.22 per cent carbon, 0.47 per cent manganese steel)								
Unground	†	6	180°	6	180°	46	66	29
Cover bead ground flush	†	6	180°					
Root bead ground flush	†			6	180°			

*Rod combination—V_3—E-7010 (root), W-E-8011 (filler), W-E-8011 (cover).
†Rod combination—U-E6010 (root), U-E6010 (filler), U-E6010 (cover).

TABLE 4. Influence of preheat, postheat, and pipe temperatures when welding 0.36-0.39 per cent, 1.24-1.28 per cent Mn steel.

Heat treatment	Weld rod	Face bead angle	Root bead angle	Weld tensile tests		
				Yield 1000 psi	Ultimate 1000 psi	Per cent elongation in 2 in.
Cooled to 25 F	*	150°	180°	74	93	29
Cooled to 25 F	‡	180°	180°	75	89	10
None (70 F)	*	160°	180°	68	91	22
None (70 F)	†	160°	180°	79	94	10
None (70 F)	‡	180°	180°	74	97	15
Preheat 250 F	*	160°	180°	75	90	12
Preheat 250 F	‡	160°	180°	73	94	15
Preheat 600 F	*	140°	155°	72	92	13
Preheat 600 F	†	130°	170°	74	94	13
Postheat 1000 F	*	180°	180°	69	93	17
Postheat 1000 F	†	180°	180°	66	85	9

*Rod combination—V_3-E7010 (root), W-E8011 (filler), W-E8011 (cover).
†Rod combination—V_2-E7010 (root), X-E10010 (filler), X-E10010 (cover).
‡Rod combination—V_1-E7010 (root), X-E10010 (filler), X-E10010 (cover).

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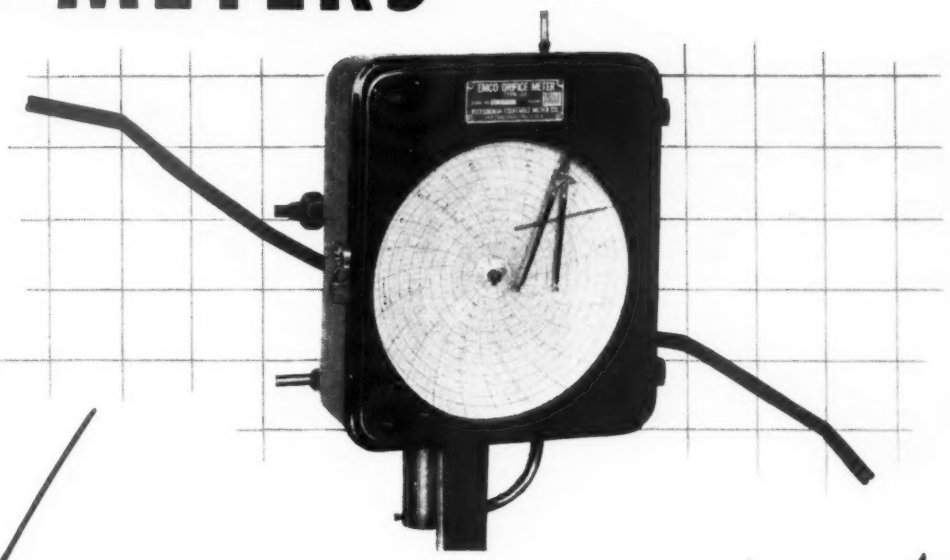

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of this bead and adversely affected the test results. There was no appreciable difference in the bend test results of normal yield (35,000 min psi) pipe. The tests reported in Table 3 were made on machine cut specimens.

● **Influence of preheat, postheat, and pipe temperature.** Although ordinary line pipe is not preheated or postheated during welding, pipe temperatures may vary. The effect of these variables on tensile and bend test results are reported in Table 4. Three specimens were used for each test. The test specimens were milled and the bead, under tension in bending, was ground flush with pipe surface. Preheat had little effect on the bend test results due to the loss in temperature during welding. Postheat showed possible improvement in bend test results and this may indicate the metallographic structure adjacent to the cover bead is affected by the postheat treatment and the residual stresses may be more completely removed. No appreciable differences in bend test results were found in pipe temperatures of 25 to 250 F.

In pipe line welding, the root bead is generally subjected to the greatest cooling rate and, therefore, is most susceptible to cracking. This bead, however, is subject to a tempering treatment resulting from deposition of the filler bead. The filler bead receives a similar treatment when the cover bead is deposited. The cover bead does not receive the beneficial effects of a tempering treatment. In the bend test, the surface contour of the cover bead produces a notch effect and the area at the notch is subjected to the greatest stress concentration. Therefore, in a sound weld, the face bend is more generally susceptible to failure.

● **Results with various types of weld rod combinations.** In the welding of ordinary line pipe, a low tensile rod such as E6010 is generally used. The cover bead with reinforcement not only strengthens the cross section of a weld in the tensile test, but, in addition, is responsible for a special type of stress distribution developed in the bend test. Therefore, not only the strength characteristics of the weld metal, but the type of weld beads, particularly the face bead, are significant.

Special consideration with reference to bend test results, should be given to the weld rod combination used in the welding of high yield strength line pipe. The shape of the weld beads used for high yield strength line pipe welds (Fig. 1) were similar to the practice used for ordinary line pipe. In this investigation, various weld rod combinations were studied and the results are summarized in Table 5. The test specimens were milled and the bead, under tension in the bend test, was ground flush with the pipe surface.

All weld rods were coated. The lime base coated rod was not included since additional development work is necessary before this rod is applicable to all-position welding. The influence of hydrogen on the cracking susceptibility of steel is recognized and, although the

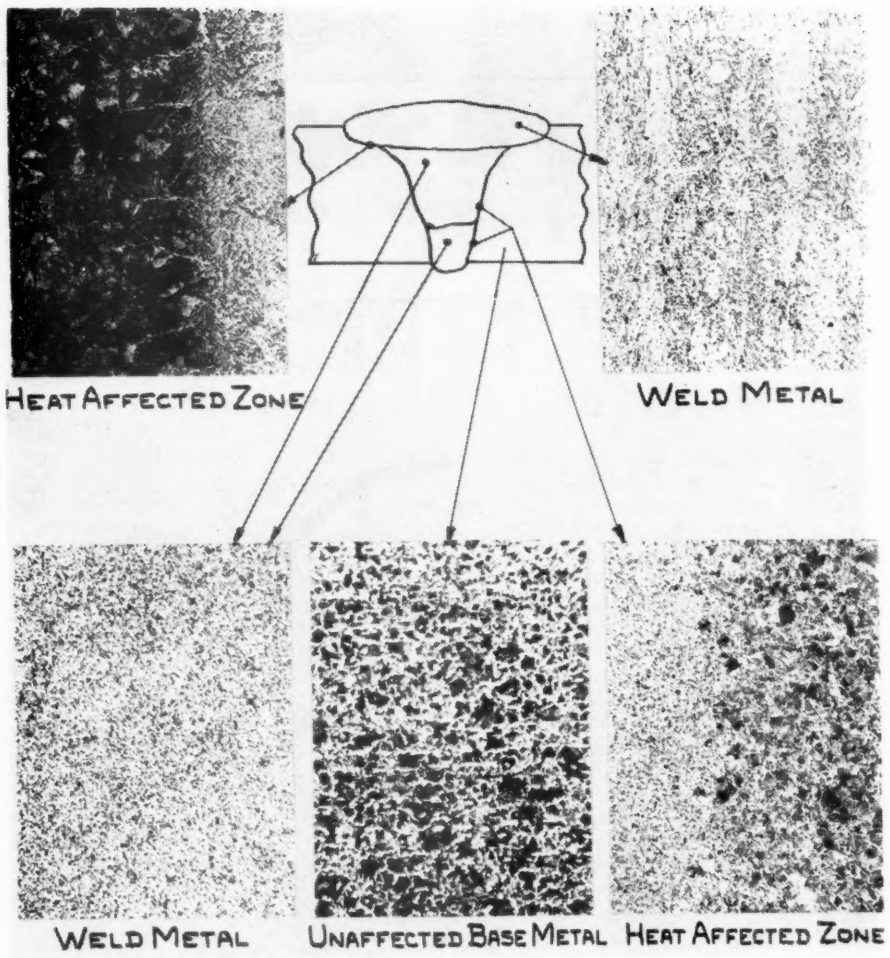
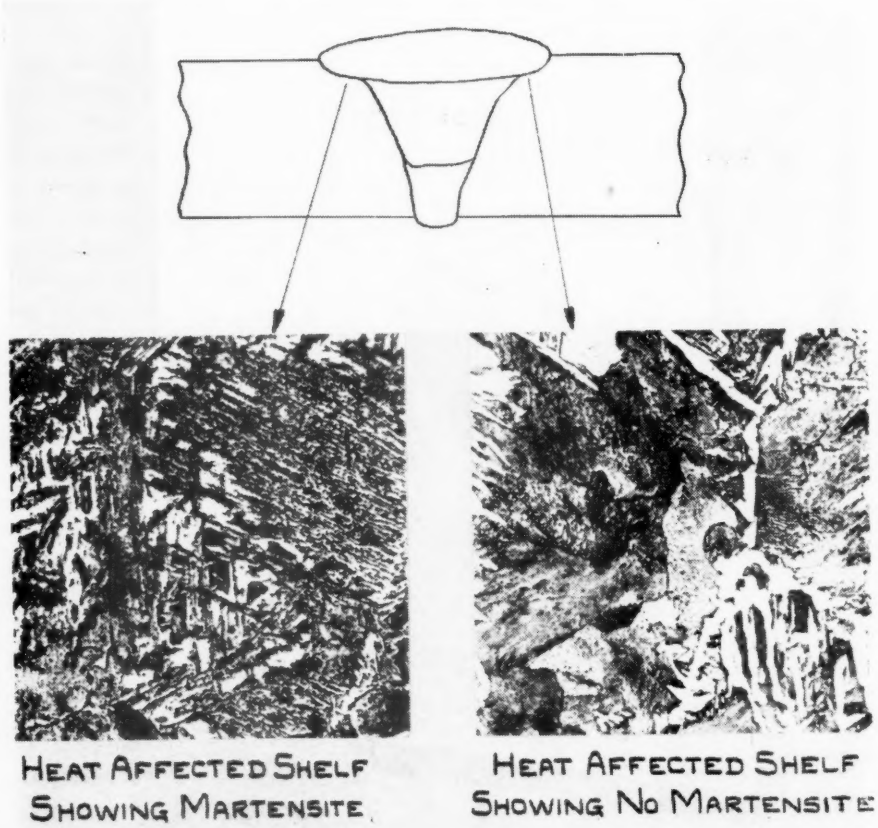


FIG. 4. Microstructure girth welds—magnification 100 × —etchant picral-nital.

FIG. 5. Microstructure martensite-girth welds—magnification 1000 × .



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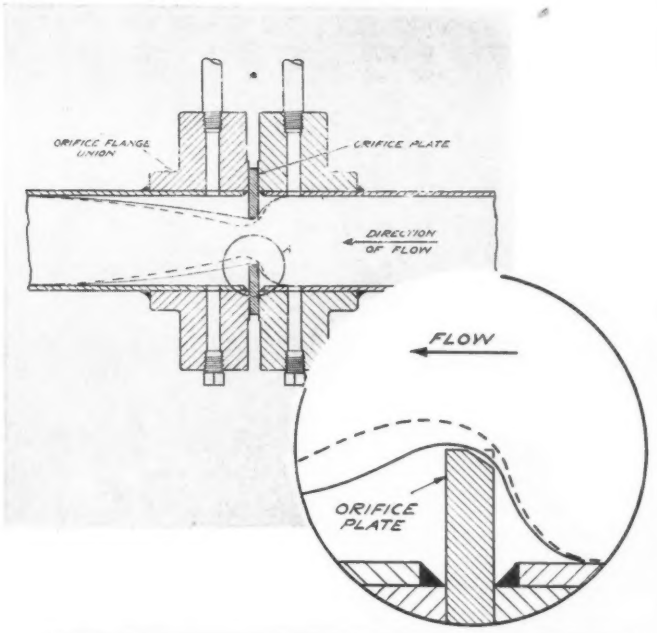

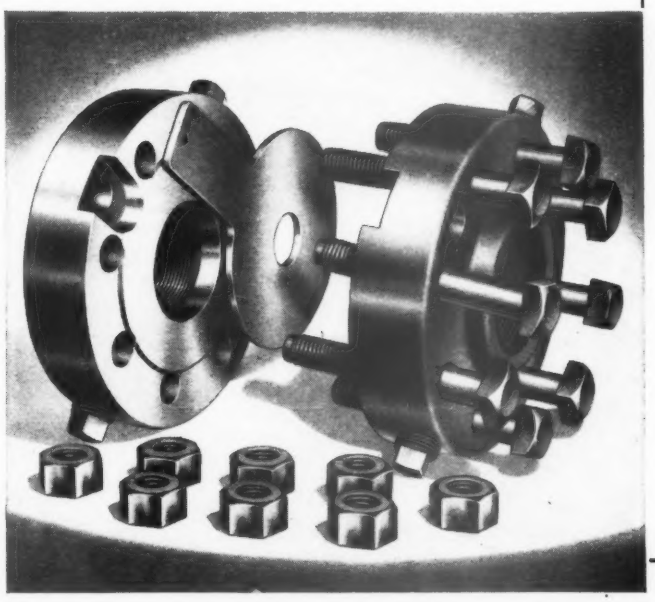

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TABLE 5. Effect of various welding rod combinations on bend and tensile tests of 0.36-0.39 per cent C, 1.24-1.28 per cent Mn steel.

Type of weld rod					Weld tensile tests		
Root	Filler	Face	Root bend angle*	Face bend angle*	Yield 1000 psi	Ultimate 1000 psi	Per cent elongation in 2 in.
U	U	U	180°	180° (b)	63	89	9
X	U	U	180°	115°	74	89	9
U	X	U	180°	90°	72	97	17
X	X	U	180°	70° (a)	75	102	17
X	X	X	180°	180° (b)	73	97	15
U	X	X	165°	130°	70	106	17
X	U	X	180°	170° (b)	71	94	21
U	U	X	180°	165°	70	84	8
V_2	V_2	V_2	180°	85°	72	93	21
W	W	W	180°	170° (b)	73	95	18
V_1	V_1	V_1	180° (b)	150°	62	88	16
V_2	X	X	180°	165°	72	98	16
V_2	W	W	170°	160°	65	95	16
V_1	X	X	180°	170°	76	95	16

*All results represent an average of three tests except (a) 1 test, and (b) 2 tests.
Rod Type: U-E6010, V_1-E7010, V_2-E7010, W-E8011, X-E10010.

TABLE 6. Influence of chemistry on tensile and bend tests.

Code no.	C	Mn	Weld rod* combination	No. tests each group	Face bend angle	Root bend angle	Weld tensile tests		
							Yield 1000 psi	Ultimate 1000 psi	Per cent elongation in 2 in.
C	0.22	0.47	U-U-U	6	180°	180°	46	66	29
A	0.37	1.27	V_1-X-X	6	165°	180°	74	98	19
B	0.38	1.42	V_1-X-X	5	149°	186°	90	105	16

*Welding Rods: U-E6010, V_1-E7010, X-E10010.

TABLE 7. Influence of chemistry on hardness and microstructure.

Code no.	C	Mn	No. of tests	DPH hardness				Microstructure
				Unaffected base metal maximum 10 kg load	Heat affected zone max. 1 kg load	Weld metal maximum 10 kg load	Heat affected zone max. 0.5 kg load	
A	0.35	1.26	8	207	266	210	258	Pearlite, bainite and ferrite without any martensite.
B	0.38	1.42	4	223	357	230	452	2 to 20 per cent martensite.

commercial aspects of the low hydrogen rod place certain restrictions on its use in line pipe welding, the technical significance of this development is of general interest.

It will be noted in Table 5 that little difference was observed in the root bend tests with various types of weld rod combinations. Variation in the face bend results were obtained. Although the E6010-E6010-E6010 rod combination resulted in satisfactory bends, the weld yield strength and elongation were low and all tests broke in the weld. Whenever more than one bead of E6010 rod was used, the weld tensile test elongation was generally low. It is interesting to note that whenever a high strength rod is used in either the first or second beads and covered with a soft E6010 rod, the face bend tests were generally poor. For these reasons, a higher strength rod than E6010 was used for the grade of steel under investigation.

The results with relatively high strength rods E10010 or E8011 in all three beads were slightly superior to the use of an E7010 rod for the root bead, followed by two beads of either E10010 or E8011 rods. These combinations appeared to be preferable to the use of E7010 rods for all three beads.

In addition to the bend test results, it is significant to observe the tensile test results. The tensile test fractures of those weld rod combinations that showed improvement in the bend test were usually located in the unaffected base plate. With the use of a high strength weld rod combination and excess weld metal in the face bead, the tensile properties of welded high yield strength line pipe, with the exception of the elongation, should be essentially dependent upon the strength of the base plate material. The bend test results, due to their relationship to ductility and welding technique of individual welders, are subject to greater variation in the welding of high yield strength line pipe.

Tests of this type do not evaluate the material with regard to cracking susceptibility in the same manner as a radiograph of the weld. Radiographic tests were conducted and are described later.

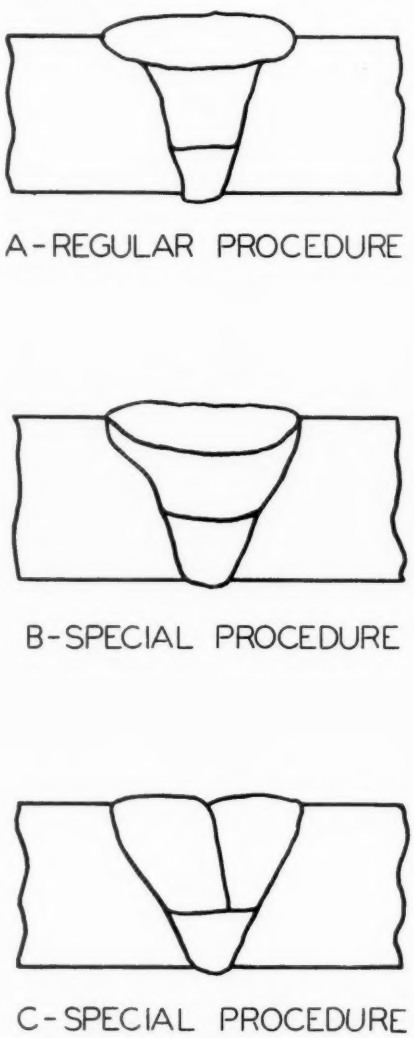
The weld rod combination used in the field welding of high yield strength line pipe is particularly significant with reference to conventional tensile and bend test results. In addition, the welding technique, particularly with reference to the skill of the welder, should be recognized. Not only does the nature of the face bead exert an influence on the test results obtained, but the technique in applying the root bead is particularly significant.

● **Influence of chemistry on girth welds.** A number of girth welds made in accordance with the procedure described in Fig. 1 were examined in order to evaluate the influence of chemistry on the structure and properties of the welded pipe joint. The bend and tensile test results are shown in Table 6. It will be noted that the bend tests in ordinary line pipe, Code C (Grade B- 20-in. OD by 0.312-in. wall) were 180 deg. The tensile tests corresponded to the grade of steel involved and the specimens broke in the base plate.

The 26-in. OD by 0.303-in. wall pipe (Code A) with a chemistry of 0.37 per cent carbon, 1.27 per cent manganese had root bends that withstood 180-deg bend, but several failures occurred in the face bend tests, although the average angle of bend was nearly 180 deg. The yield and ultimate strengths of the weld tensile tests were much higher compared to ordinary Grade B line pipe material, due to the higher chemistry pipe and weld rod. The elongation was lower and the tensile tests usually fractured in the base plate, although in two instances fracture occurred in the weld.

The 18-in. OD by 0.312-in. wall pipe

FIG. 6. Special weld procedure. Root bead E7010 rod, second and third beads E10010 rods.



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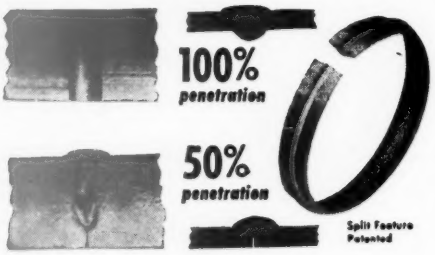

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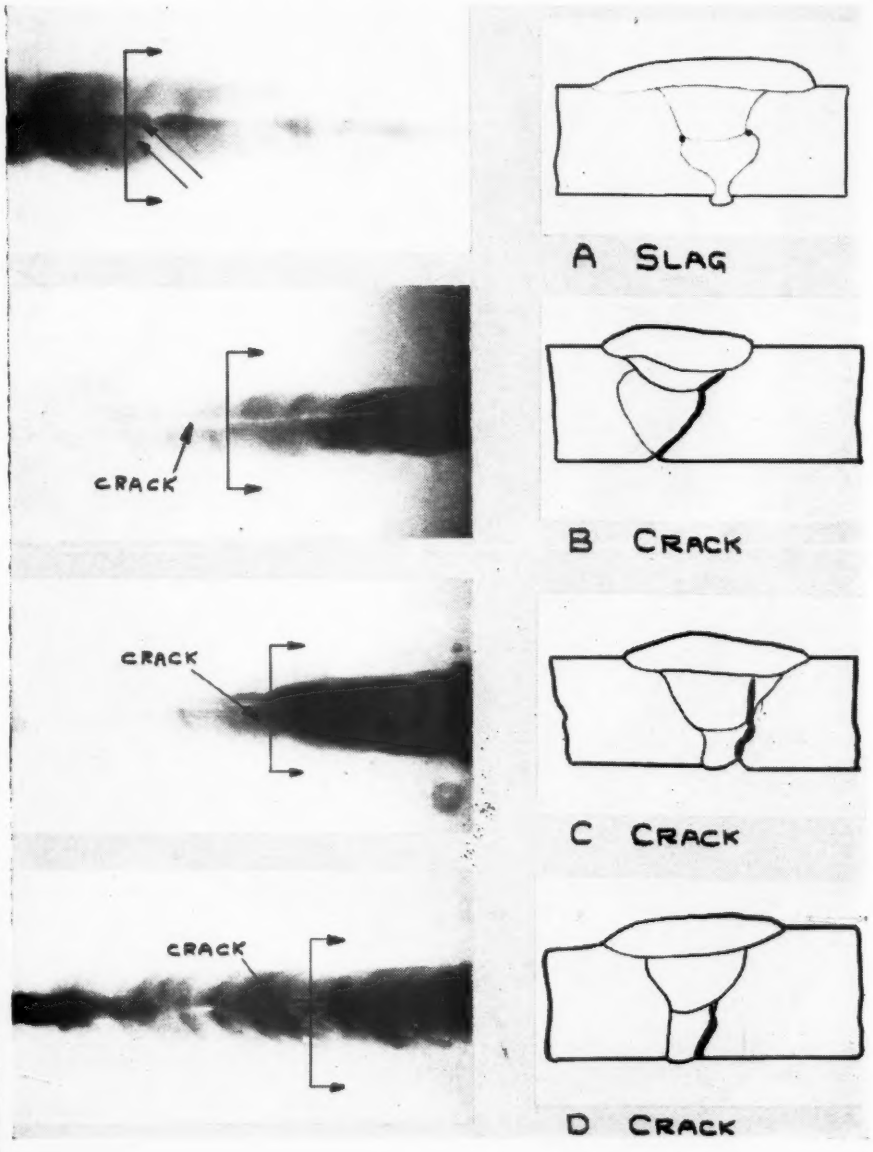
(Code B) had bend and tensile tests similar to the 26-in. OD by 0.303-in. wall pipe. The higher chemistry of the 18-in. OD pipe was responsible for the lower average angle of bend, although the angle of bend was nearly 180 deg. The high chemistry was responsible for the increased yield and ultimate strength of the weld tensile test, but decreased the elongation. Two of the weld tensile tests fractured in the weld, whereas the remainder fractured in the base plate.

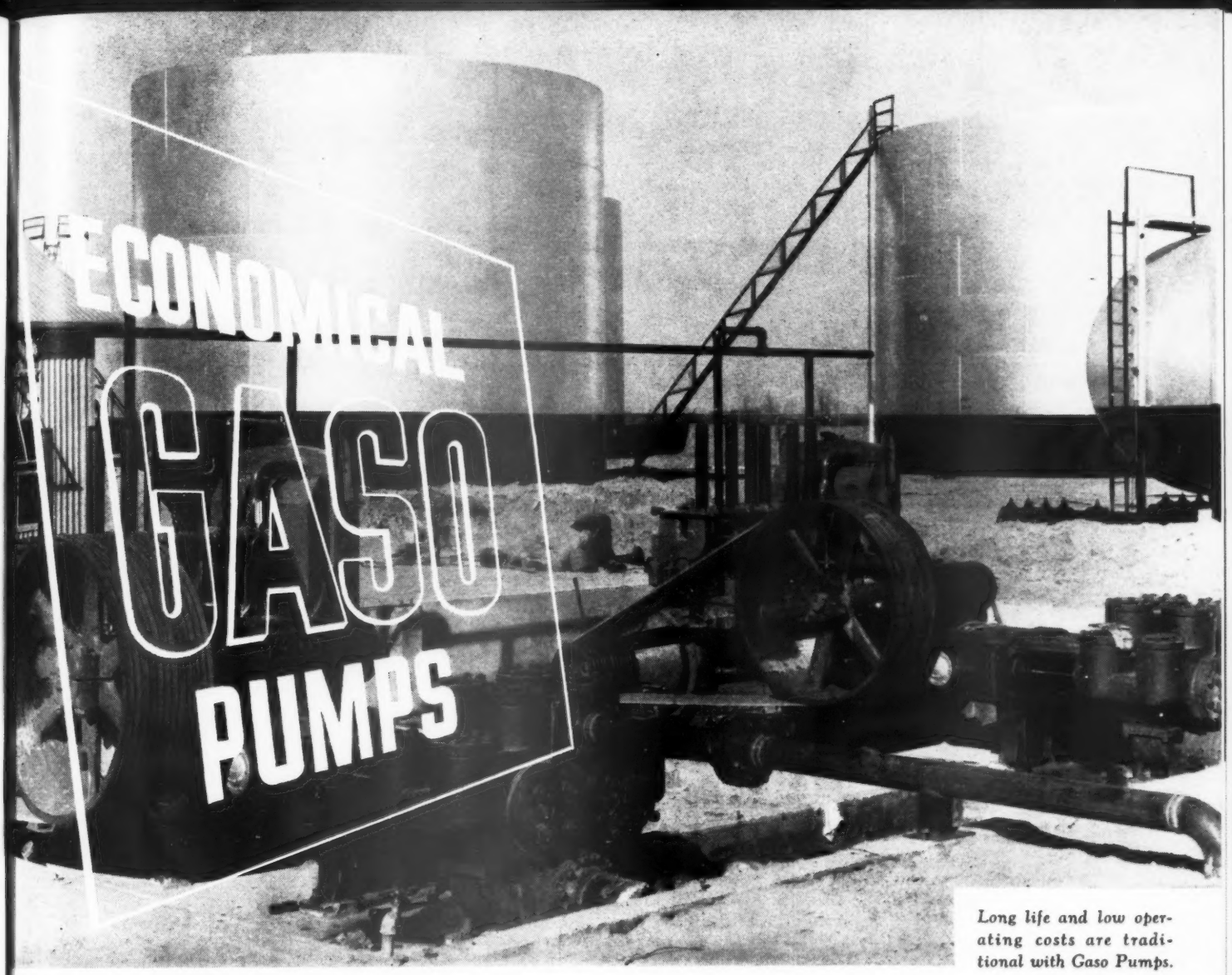
The hardness survey made in accordance with the procedure described in Fig. 2 and microstructure of several high yield strength welds are shown in Table 7. It will be noted that the maximum diamond pyramid hardness (10 kg load) of the heat-affected zone was 357 and the maximum diamond pyramid hardness (0.5 kg load) of the same zone was 452 in the high chemistry weld. Martensite was observed only in the shelf associated with the face bead of the highest chemistry weld. No cracks were observed in the hardened structure. The presence of martensite was associated with the shape of the face weld bead and the fact that this bend is not heat-treated as the filler bead or root bead. The martensite area is well surrounded with more ductile material and is not associated with mechanical stress raisers. Typical microstructures are shown in Figs. 4 and 5, and it will be noted that the weld metal and heat-affected zone of the cover bead differ from the filler or root bead.

Due to the nature of the hardness results that were associated with the shelf of the face bead, different methods for depositing the weld beads are suggested. In Fig. 6, two special procedures are proposed that may reduce the possible formation of martensite, and tests of these welds are in progress.

In Fig. 7, the nature of cracks observed in the X-ray tests are shown. In addition, the nature of occurrence of slag pockets or "car tracks" is shown. Cracks observed in these high yield strength welds are associated with weld-

FIG. 7. Nature of cracks in X-ray examination.





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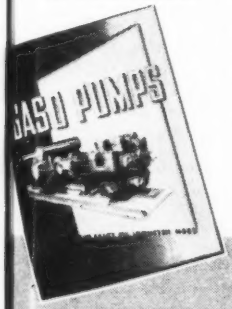

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ing technique. In approximately 500 in. of welds X-rayed, a few cracks were observed.

The crack shown in Fig. 7b was associated with poor welding technique and was due to lack of penetration in the root bead. The crack shown in Fig. 7c was also due to poor welding technique, originating at the root bead. In Fig. 7d the crack is associated with a tack weld and would not occur in pipe not tack welded. The results of the X-ray tests indicate the importance of good welding technique, which applies not only to high yield strength line pipe, but also to ordinary line pipe. The precautions to be observed in welding ordinary line pipe are not as important compared to high yield strength line pipe.

● **Influence of chemistry in bead welds.** The bead welds were made in accordance with the procedure already described and illustrated in Fig. 1. A 0.5 kg load was used in hardness testing. The hardness and microstructure in Table 8 are from weld beads deposited with a 5/32-in. rod and 17-in. per min travel speed. This type of weld bead involves extremely fast cooling rates and should be used only for a comparison of various types of steel and not directly with girth weld test results.

Although carbon is usually associated with the hardness of welds, it will be noted in Table 7 that manganese is also a factor. In steel containing 0.30-0.32 per cent C an increase from 1.12 to 1.35 per cent manganese resulted in an increase in maximum hardness. Similar results were obtained with steel containing 0.36-0.37 per cent C; however, with 0.40-0.41 per cent C material, an increase from 1.16 to 1.42 per cent manganese did not appreciably change the maximum hardness obtained due to the high carbon content of the material. These results indicate that under certain conditions, it may be more desirable to increase the carbon content in preference to manganese in order to obtain higher yield strength material. A closer relationship to the conditions encountered in girth welds will be obtained when results from tests being conducted with a 3/16-in. rod and 9-in. per min travel speed are available. In line pipe welding, carbon has usually been considered the most important factor with respect to the maximum hardness obtained in the weld. These results indicate that under certain conditions manganese may be the controlling factor.

TABLE 8. Influence of chemistry on bead welds.

Code	C	Mn	Max. hardness* DPH	Microstructure at max. hardness
D	0.30	1.12	426	M—90 per cent
E	0.31	1.26	499	M—90 per cent
H	0.32	1.35	534	M—99 per cent
F	0.36	1.14	407	M—85 per cent
G	0.37	1.36	508	M—90 per cent
I	0.37	1.37	553	M—99 per cent
J	0.41	1.16	572	M—95 per cent
K	0.40	1.34	627	M—99 per cent
L	0.40	1.42	583	M—99 per cent

*0.5 kg load.

● **Summary.** 1. Various factors relating to the bend tests in high yield strength line pipe were investigated. Removal by grinding of the mechanical notch effect of the outside bead improved the ductility of the welded joint as measured by the bend test.

2. Various types of weld rod combinations and their influence on the physical properties of the welded joint were investigated. High strength weld rod combinations involving Types E7010, E8011, and E10010 electrodes produced the best results for high yield strength line pipe.

3. The influence of chemical composition of pipe material on the physical properties of welds in high yield strength line pipe was evaluated, and the relationship of carbon and manganese developed. A minimum yield strength of 52,000 psi and minimum tensile strength of 75,000 psi were obtained with open hearth steel pipe containing 0.40 per cent max carbon and 1.40 per cent max manganese.

4. Results with X-ray analysis of girth welds in high yield strength line pipe indicated the importance of proper welding technique.

● **Acknowledgment.** The authors appreciate the help received from the management and operating personnel of National Tube Company in carrying out the experimental results of this investigation. The personnel and facilities of the U. S. Steel Corporation Research Laboratory contributed much to this investigation. ★★★

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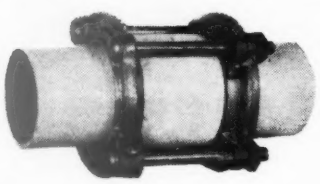

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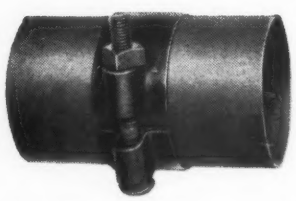

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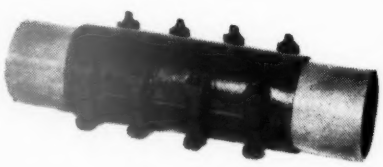

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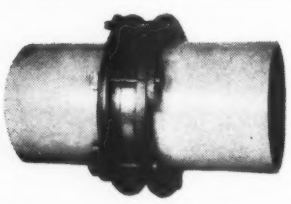

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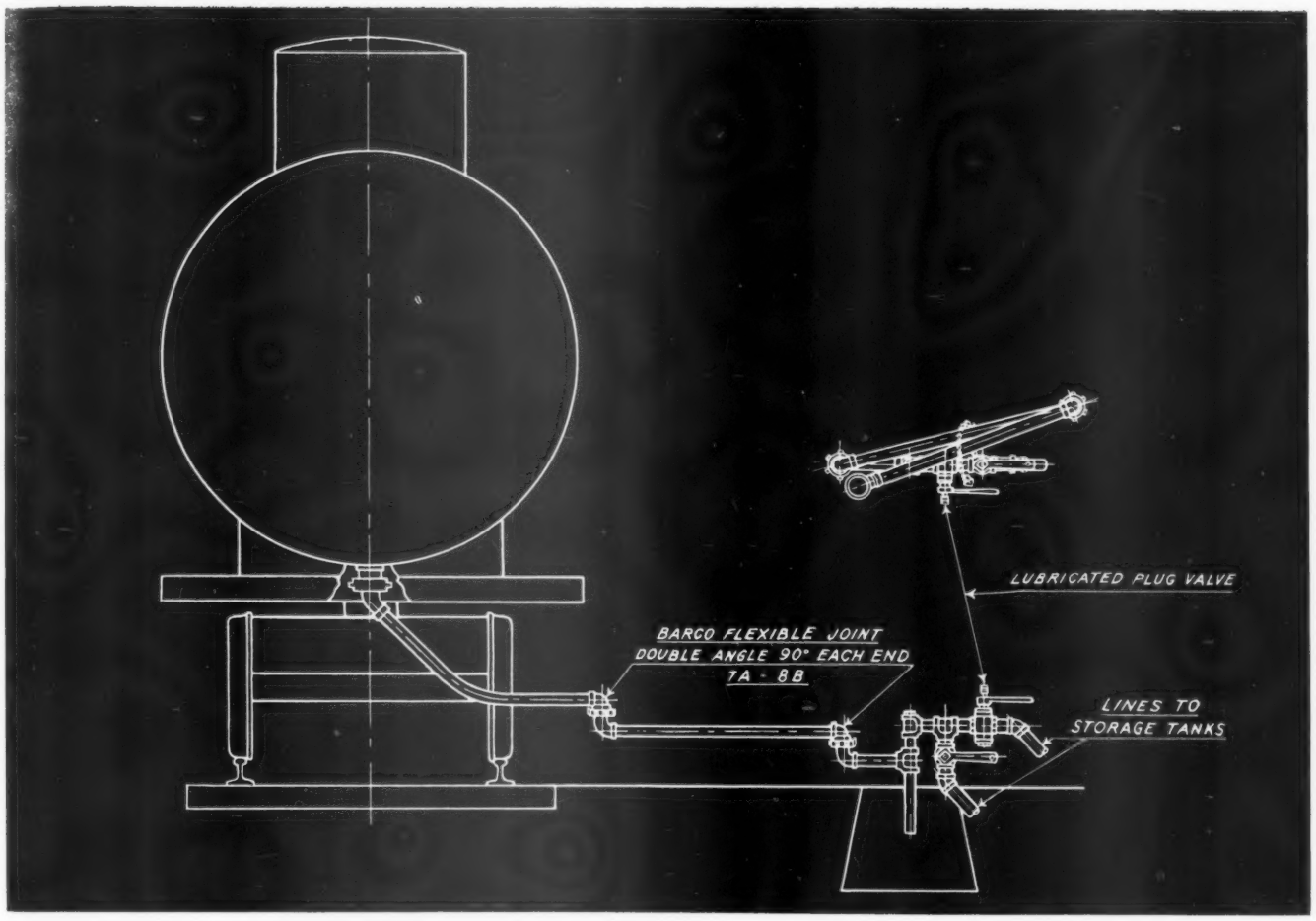

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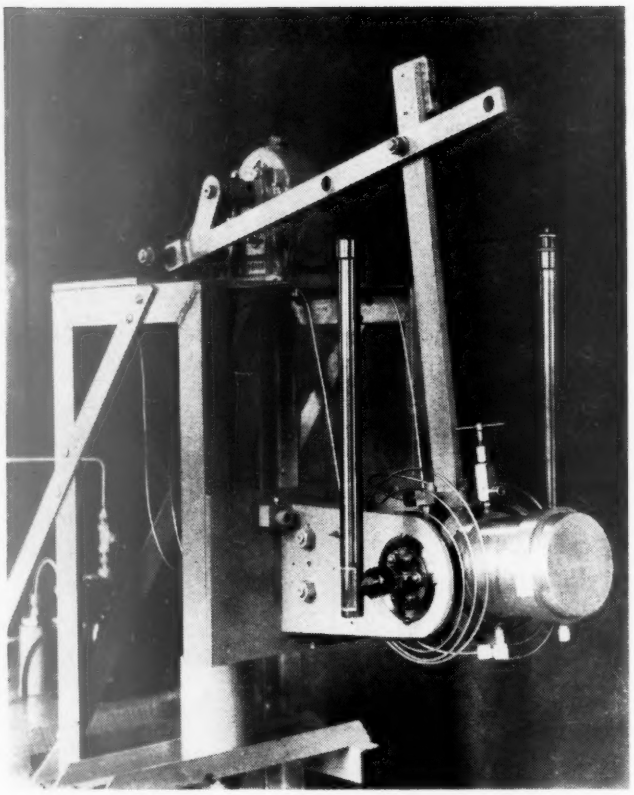

FIG. 1. The windowed cell in its mounting.

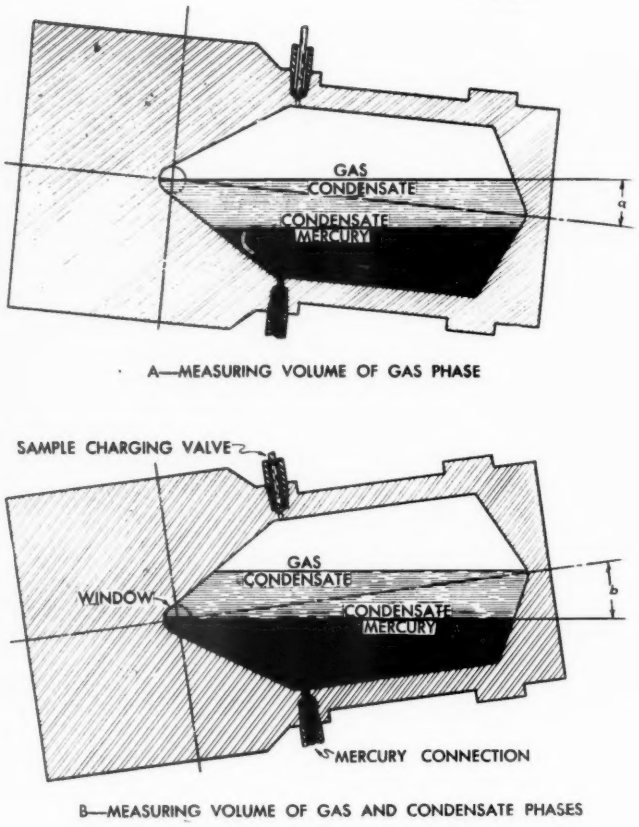

FIG. 2. Use of windowed cell for measuring volumes of the fluid in equilibrium.

Phase relations of a gas-condensate fluid at low temperatures, including the critical state*

By C. K. EILERTS†, V. L. BARR‡, N. B. MULLENS**, and BETTY HANNA§

● **Abstract.** Using a windowed cell developed by the Bureau of Mines the authors have determined the specific volumes and liquid-gas ratios of a natural gas and four mixtures of condensate with the gas at temperatures in the range minus 65 to 100F. The critical pressures and temperatures of each of the five mixtures were measured. Data for the temperatures ranging from the critical temperature (minus 63.2F) to the temperature of the cricondentherm (276F) are presented on a mixture having the composition of a fluid flowing from a gas-condensate well. Except for pressures less than 750 psi, substantially the entire two-phase region of this fluid was investigated experimentally. Pressures up to 5000 psi were used to obtain compressibility factors in the single phase region and to determine the phase boundary of the mixture.

The information regarding the properties of the hydrocarbon mixtures at low temperatures was obtained to supplement and to aid in correlating extensive data that have been obtained at flowing wells in the field by means of mobile equipment. Although useful correlations of hydrocarbon properties can be made on the basis of critical pressures and temperatures computed by additive methods, it is believed that such methods of correlation can be extended to new applications with increased accuracy by using actual values of the critical pressures and temperatures of mixtures. Measured values of the critical pressures of the mixtures investigated averaged more than 100 per cent higher than pressures computed by additive methods. Measured values of critical temperatures differed from computed values by extremes of 7 per cent on an absolute temperature basis.

An unexpected finding was that the critical temperature of the separator gas was higher than the critical tem-

*Presented at the Fall Meeting of the Petroleum Division, American Institute of Mining and Metallurgical Engineers, Tulsa, Oklahoma, October 8, 1947. Published by permission of the Director, Bureau of Mines, U. S. Department of the Interior.

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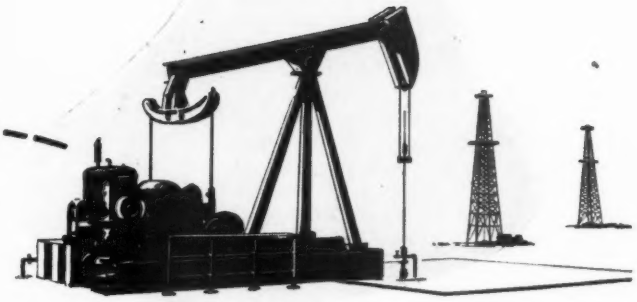

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perature of the gas-condensate fluid flowing from the well. It is significant that experimental values of critical temperatures of mixtures particularly pertinent in production practice did not vary with the composition on an additive basis. For these mixtures the critical temperature was found to be higher the more gas and the less condensate they contained.

The compressibility factors and the liquid-gas ratios of a gas were determined over a pressure and temperature range that included atmosperic conditions and conditions providing total liquefaction. The results obtained can be a useful guide in problems of transmission and of high pressure and low-temperature storage.

WORK with a windowed cell, developed by the Bureau of Mines, has indicated that the values of critical pressures and temperatures of gas-condensate fluids determined by direct measurement cannot be computed accurately from the composition of the fluids by methods now available. The measured and the estimated values of the critical temperature may differ by 7 per cent, and critical pressures determined by the two methods may differ by as much as 100 per cent.

Cope, Lewis and Weber[1], and Brown, Souders, and Smith[2] have shown how critical pressures and temperatures and the related functions, reduced pressures and temperatures, may be used to correlate pressure-volume-temperature relations of paraffin hydrocarbons. Kay[3] introduced the concept of the "pseudo-critical point" and applied it in estimating by additive methods the compressibility factors of hydrocarbon mixtures. Calculated values of the critical pressures and temperatures of hydrocarbon mixtures have been very useful for estimating the specific volumes of gases under pressure in natural reservoirs and in flow lines. It will be most helpful if the usefulness of the reduced pressure and temperature concept can be extended to estimating such properties as liquid-gas ratios and dew-point pressures of hydrocarbon fluids under pressure.

The design of apparatus for measuring the properties of natural hydrocarbon fluids at the critical state depends on the critical temperature of the fluid to be studied and whether a static or dynamic procedure is to be used. Using a static method, Katz, Vink and David[4] measured the critical temperature of a mixture of gasoline and natural gas by means of a liquid-level gage. Buckley and Lightfoot[5] demonstrated the use of field equipment and the possibilities of a dynamic method for estimating the critical state of a gas-condensate system. One of the authors, in discussing a paper by Reid[6], showed how results obtained by operating dynamic equipment at pressure exceeding wellhead pressures could be used to define the phase-boundary properties of gas-condensate systems.

Results obtained in the field by the Bureau of Mines in 1943-45, using mobile equipment, showed that it usually is impracticable to operate dynamic equipment at temperatures lower than 70 F because gas hydrates that form in the fluid withdrawn from the well interfere with the flow of the sample through the test equipment. Experience gained in the field with a window assembly designed to withstand high pressures indicated that laboratory equipment containing windows might be constructed and used to determine the critical state of gas-condensate fluids by a static method. On the basis of this experience, the windowed cell[7] was constructed for operation at low temperatures, and windows of the type used in the mobile equipment were included to permit measuring liquid-gas ratios and fluid volumes.

● **Operating principle of the windowed cell.** The most important function of the cell is the measurement of liquid-gas ratios of mixtures under temperature and pressure conditions such that the liquid volume of the contained sample is an appreciable fraction of the total fluid volume. The windows permit the cell to be used also for measuring the specific volume and compressibility of fluids and for determining their bubble-point and dew-point phase boundaries over a wide range of temperatures and pressures.

Fig. 1 is a photograph of the cell mounted on its trunnion bearings but not enclosed by the constant-temperature bath. The operating principle of the cell is illustrated in Fig. 2. The volume of a hydrocarbon fluid in the cell is increased by withdrawing an amalgam of thallium from the cell — the maximum volume that can be attained is 833 cc. Glass windows diametrically opposite each other in the walls of the cell provide a means for observing and measuring the volume of the phases within the cell. The line through the center of the windows is the axis of a trunnion mounting on which the cell is rocked to agitate its contents. The cell is rotated on this mounting when the volumes of the confined hydrocarbon phases are to be measured.

The method of measuring the volume of the gas phase of a sample in the windowed cell is illustrated in Fig. 2, section A. Equilibrium between the gas and liquid phases is established by rocking the cell and adjusting the volume of the sample until no further volume changes are necessary to maintain a given pressure at a given temperature within the cell. The cell is then rotated on the trunnion mounting until the condensate-gas meniscus coincides with a mark in the exact center of the glass window. The angle a between the lengthwise axis of the cell, and the horizontal is measured by means of a

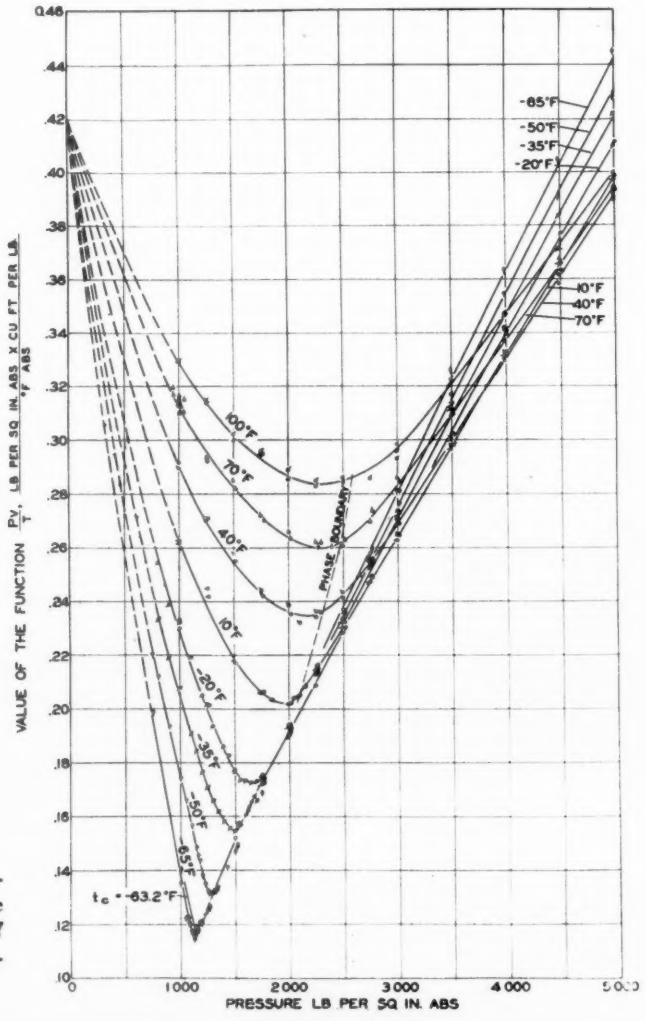

FIG. 3. Specific volume data for mixture containing 72.47 mass per cent separator gas.

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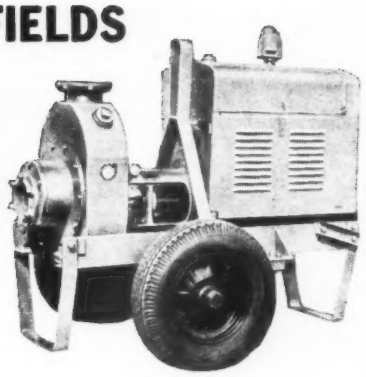

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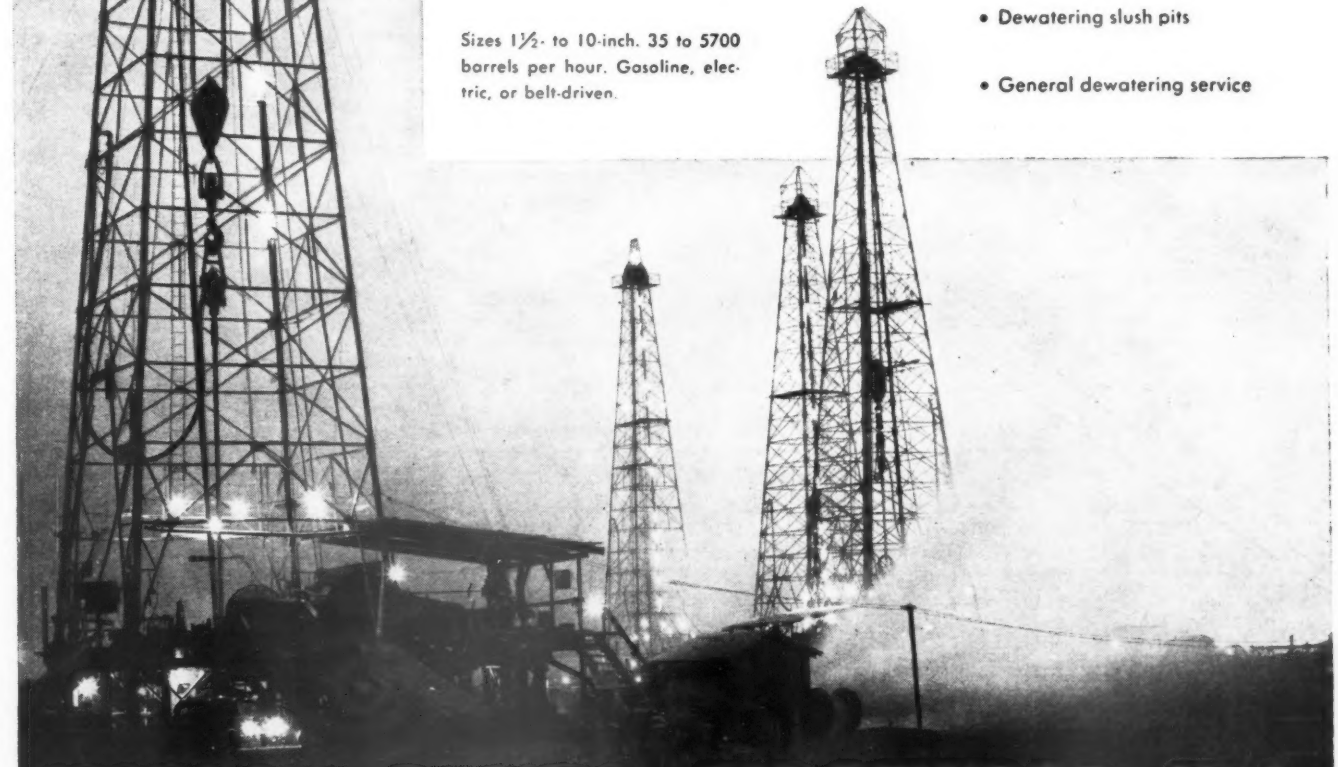

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clinometer to determine the volume of the gas. The volume of the cell above a horizontal plane through the centers of the windows is known for values of the angle *a* determined by prior calibration. After angle *a* has been measured and the volume of the gas determined (Fig. 2, section A), the cell is rotated until the condensate-mercury meniscus coincides with the center of the window and angle *b* can be measured (Fig. 2, section B). Knowing angle *b*, the volume of the gas- and liquid-hydrocarbon phases combined can be determined. The volume of the liquid-hydrocarbon phase then is obtained by subtracting the volume of the gas phase from the combined volumes of the gas and liquid phases. All measurements are made without changing the volume, pressure, or temperature of the sample. A complete description of the windowed cell and the methods used in operating it are given in a former publication[7].

● **Preparation of hydrocarbon mixtures.** The fluid from the gas-condensate well that provided the hydrocarbon material for this investigation was separated into its gas and liquid phases before samples were taken for the subsequent laboratory work for which the windowed cell was used. The phases were recombined in the cell in the proportions of the liquid-gas ratio measured at the well when the samples were obtained to provide the mixture referred to in this report as the flowing fluid (mixture containing 72.47 mass per cent separator gas). The phases were combined in other proportions, also, to obtain an indication of the effects of variation in composition on the properties of the mixtures. In preparing the mixtures, a portion of the gas-phase sample was introduced into the cell first and its mass determined by measuring the pressure, temperature, and volume of the gas. The volume of liquid-phase sample that was required for mixing with the gas was measured into the cell under pressure by means of the displacement meter. This is a calibrated instrument designed on the principle of a hypodermic syringe but constructed of steel for high pressure service.

The gas and liquid phases for all mixtures prepared in the cell were measured under a pressure of 1000 psia while the temperature was maintained at 70 F. The mass of the gas part of a mixture was computed from predetermined compressibility data and specific volume measurements made at atmospheric pressure. The mass of the liquid part of a mixture was computed from the volume of the liquid displaced into the cell and the specific volume of the liquid measured with a high pressure, steel pycnometer at displacement pressure and temperature The accuracies of the measurements were such that the statements of the composition of the mixtures on a mass-per cent-gas basis are subject to an uncertainty estimated to be less than 0.5 per cent.

● **Composition of the mixtures.** The composition of the mixtures of separator gas and hydrocarbon liquid that were investigated in the cell is reported in Table 1 on mass fraction and mole fraction bases. The analyses of the mixtures for the lighter components were made by low temperature fractional distillation. (These components ranged from methane to a heptanes fraction having a vapor pressure of 35 to 17 mm of mercury at 32 F). The distillation apparatus, which consists of three jacketed columns operated in series, has been described in published literature[8, p. 12]. Experience with the equipment indicates that the mole fraction uncertainty in the analytical results ranges from 0.0005 for ethane to 0.00005 for the heptanes. The components heavier than the fraction having a vapor pressure of 17 mm of mercury are arbitrary designations based on a Hempel distillation of the condensate. The treatment of Hempel-distillation data to obtain distribution of the components also has been described [9, p. 52]. This method of analysis does not involve a fractionation as accurate as that obtained with the low-temperature columns, but it does provide a useful measure of the distribution of components with a molecular weight of 100 or more in the mixtures.

● **P-V-T relations of flowing fluid.** The mixture containing separator gas and liquid in the proportions in which they flowed from the well (72.47 mass per cent gas) was the most important of the mixtures prepared and tested in the cell. The liquid-gas ratio determined at the separator while the samples were being taken was 88.74 bbl (288.1 lb-moles) of separator liquid, measured at 645 psia and 82 F, per million cu ft (2582.3 lb-moles) of separator gas and referred to a base of 14.4 psia and 60 F. Previous field investigations of the properties of the flowing fluid provided data that indicated[10], (Fig. 7) that the true critical temperature conceivably might be higher than the computed "pseudocritical" temperature (minus 35 F).

The properties of the flowing fluid were determined over the temperature range minus 65F to 100F at pressures from 750 to 5000 psia. The mercury-thallium amalgam used in the cell to vary the volume of the sample had a melting point just low enough to permit operating the cell at temperatures lower than the critical temperature of the mixture. Data were also obtained at temperatures lower than minus 70F (when the amalgam was frozen solid) by means of a constant-volume, variable-pressure-temperature procedure, but these data are not included in the present report.

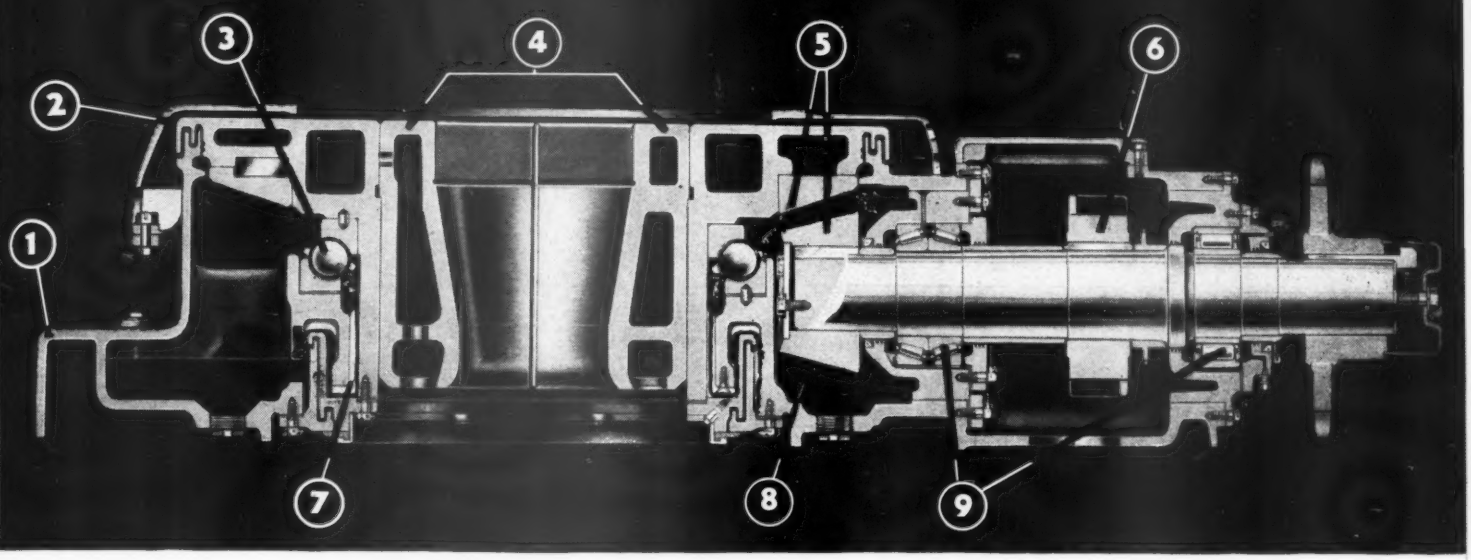
The P-V-T relations of the mixture representing the flowing fluid are illustrated in Fig. 3, which shows the variation in the value of the function Pv/T with temperature and pressure.

TABLE. 1. Composition of mixtures of separator gas and liquid.

Component	Separator liquid		63.71 mass per cent gas		68.09 mass per cent gas		72.47 mass per cent gas*		84.04 mass per cent gas		Separator gas	
	Mole fraction	Mass fraction	Mole fraction	Mass fraction	Mole fraction	Mass fraction	Mole fraction	Mass fraction	Mole fraction	Mass fraction	Mole fraction	Mass fraction
Carbon dioxide	0.007,94	0.005,09	0.007,96	0.012,88	0.007,95	0.013,41	0.007,94	0.013,95	0.007,95	0.015,36	0.007,94	0.017,31
Nitrogen	0.003,43	0.001,40	0.013,28	0.013,69	0.013,54	0.014,54	0.013,75	0.015,39	0.014,30	0.017,61	0.014,90	0.020,69
Methane	0.164,84	0.038,50	0.737,10	0.434,65	0.751,79	0.461,90	0.764,32	0.489,59	0.796,56	0.561,09	0.831,20	0.660,34
Ethane	0.078,30	0.034,27	0.079,35	0.087,70	0.079,35	0.091,38	0.079,23	0.095,12	0.079,34	0.104,75	0.079,34	0.118,14
Propane	0.101,24	0.064,99	0.045,89	0.074,38	0.044,42	0.075,02	0.043,01	0.075,72	0.039,96	0.077,37	0.036,51	0.079,72
Isobutane	0.047,70	0.040,36	0.013,72	0.029,30	0.012,82	0.028,54	0.011,98	0.027,79	0.010,10	0.025,77	0.007,99	0.023,00
Normal butane	0.088,75	0.075,09	0.022,02	0.047,05	0.020,27	0.045,12	0.018,62	0.043,20	0.014,94	0.038,12	0.010,80	0.031,08
Isopentane	0.063,64	0.066,85	0.011,99	0.031,80	0.010,63	0.029,38	0.009,37	0.026,98	0.006,51	0.020,61	0.003,31	0.011,83
Normal pentane	0.056,93	0.059,79	0.010,18	0.027,00	0.008,96	0.024,74	0.007,81	0.022,49	0.005,22	0.016,53	0.002,33	0.008,32
135-56 hexanes	0.059,96	0.075,22	0.009,97	0.031,59	0.008,67	0.028,60	0.007,44	0.025,61	0.004,67	0.017,67	0.001,58	0.006,74
56-35 hexanes	0.054,87	0.068,84	0.008,94	0.028,32	0.007,74	0.025,54	0.006,61	0.022,75	0.004,07	0.015,40	0.001,23	0.005,25
35-17 heptanes	0.025,31	0.036,92	0.003,98	0.014,66	0.003,42	0.013,13	0.002,90	0.011,62	0.001,72	0.007,55	0.000,40	0.001,98
17 heptanes	0.027,01	0.037,15	0.003,89	0.014,33	0.003,33	0.012,77	0.002,95	0.011,14	0.001,60	0.007,06	0.000,27	0.001,34
Octanes†	0.095,04	0.149,01	0.013,70	0.057,51	0.011,71	0.051,22	0.010,40	0.044,70	0.005,64	0.028,30	0.000,95	0.005,37
Nonanes†	0.056,00	0.098,62	0.008,08	0.038,07	0.006,90	0.033,89	0.006,13	0.029,58	0.003,33	0.018,73	0.000,56	0.003,56
Decanes†	0.031,01	0.060,57	0.004,47	0.023,37	0.003,82	0.020,81	0.003,38	0.018,17	0.001,84	0.011,50	0.000,31	0.002,18
Undecanes†	0.016,01	0.034,34	0.002,31	0.013,25	0.001,97	0.011,80	0.001,76	0.010,30	0.000,95	0.006,52	0.000,16	0.001,24
Dodecanes†	0.014,01	0.032,74	0.002,02	0.012,63	0.001,72	0.011,25	0.001,53	0.009,82	0.000,83	0.006,22	0.000,14	0.001,18
Tridecanes†	0.008,01	0.020,25	0.001,15	0.007,82	0.000,99	0.006,96	0.000,87	0.006,08	0.000,47	0.003,84	0.000,08	0.000,73
	1.000,00	1.000,00	1.000,00	1.000,00	1.000,00	1.000,00	1.000,00	1.000,00	1.000,00	1.000,00	1.000,00	1.000,00
Av. molecular wt.	68.64		27.19		26.09		25.03		22.76		20.18	

Specific volume of the separator liquid = 0.025,20 cu ft per lb at separator pressure (645 psia abs) and separator temperature (82 F).
*The flowing fluid (mixture of gas and liquid in the proportion in which they flowed from the separator).
†Arbitrary designation based on Hempel distillation of condensate.

"INSIDE STORY"



—is the "Inside Story" of ALL "Oilwell" Rotaries!

1—Rigid one-piece cast-steel base has pinion-shaft bearing supports, table enclosure, oil reservoir and skids cast integral.

2—Elevated safety guard prevents mud being slung onto the derrick floor. Flared sides of guard (patented) prevent mud "bridges" from building up and allowing mud to overflow into oil compartment.

3—Table turns freely on large-diameter high-precision steel balls in self-centering angle-contact bearing with races of through-hardened, high-carbon, alloy steel.

4—Table has full 20½-inch opening.

5—Quiet-operating spiral-bevel gear train is made from alloy-steel forgings, heat-treated for maximum toughness and wear-life. Pinions have surface-hardened teeth.

6—Three-way locking against either clockwise, counter-clockwise or all rotation is achieved by means of a hand lever which selectively engages this locking-dog wheel.

7—Extra-wide, heavy-duty bronze radial and hold-down bushing, low in the base, is continuously submerged in oil and serves as a steadying bearing for the turntable, while absorbing upward thrust. Foreign matter from blowouts is prevented from entering the rotary by a labyrinth and flexible sealing ring.

8—12-gallon capacity oil reservoir extends completely around table. It is sealed at the top by an improved labyrinth and at the bottom by a hold-down ring that is bolted to and rotates with the turntable. The lip of the hold-down ring overlaps the retaining ring, thus assuring the return of all oil to the oilbath at any speed. The pinion, dipping in the oilbath, carries oil to the bevel gear, where it is sprayed continuously to the main bearing from where it flows to submerge the hold-down bearing.

9—Compact and sturdy pinion-shaft assembly is mounted at the pinion end in opposed heavy-duty tapered roller bearings, designed for both radial and thrust loads, and at the sprocket end in a heavy-duty straight roller bearing. Both bearing housings are grease-packed. The pinion shaft bearings, lockwheel, tachometer-drive sprocket and spacers are locked endwise on the large-diameter shaft in such a manner that either bearing assembly can be removed without stripping the entire shaft.

OIL WELL SUPPLY COMPANY ★ USS ★ UNITED STATES STEEL

***ALL ROTARIES IN THE "OILWELL" LINE** are similar in general construction—differing only in size and capacity. Your nearest "Oilwell" representative will gladly furnish complete information, to assist in selecting the Rotary best suited for your drilling requirements.*

BRIEF SPECIFICATIONS

"Oilwell" Oilbath Rotaries	17½ A&B	20½-inch	21-A	27½-A
Gear Ratio	3.28:1	3.82:1	2.61:1	3.84:1
Rated Dead-Load Capacity ....tons	200	250	300	350
Recommended Max. Drlg. Depth...feet	9,000	13,000	17,000	17,000
Recommended Max. Table Speed .....r.p.m.	500	500	1,000	400

OIL WELL SUPPLY COMPANY

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UNITED STATES STEEL

"OILWELL"

The specific volumes v and the compressibility factors Z of the mixture at different pressures and temperatures were computed from the smooth curves drawn through the experimental data presented in Fig. 3 by use of the equation:

$$\frac{Pv}{ZT} = b \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (1)$$

Where:

P = pressure, psia,
v = specific volume, cu ft per lb,
Z = compressibility factor, dimensionless,
T = temperature, F abs,
b = limit value of the function Pv/T as zero pressure is approached. For the mixture containing 72.47 mass per cent of gas the value of b was 0.419, 8.

The specific volume and compressibility data obtained on the mixture containing 72.47 mass per cent gas are reported in Table 2. It is estimated that the values of the function Pv/T shown in Fig. 3 and used to compute values of v and Z shown in Table 2 are subject to a precision uncertainty of 0.5 per cent.

The limit value b of the function Pv/T as the pressure approached zero was computed by using equilibrium factors. The volume that would be occupied by the separator gas in the mixture at a pressure of 14.4 psia and a temperature of 70 F was known from previous work with the gas. Determination of the compressibility of the gas will be described later in this report. The volume of the dissolved gas that would be liberated from the separator liquid at a pressure of 14.4 psia and a temperature of 70F in the presence of the separator gas was

TABLE 2. Properties of the mixture (flowing fluid) containing 72.47 mass per cent separator gas.

Pressure, psia	−65 F				−50 F				−35 F				−20 F			
	v	Z	L/F	l:g	v	Z	L/F	l:g	v	Z	L/F	l:g	v	Z	L/F	l:g
5000	0.034,91	1.053,8	1.000,0	..	0.035,29	1.026,2	C.CCO,C	0.00	0.035,72	1.002,1	0 000,0	0.00	0 036,07	0.977,4	0.000,0	0.00
4500	C.035,33	0.959,7	1.000 0	..	0 C35,81	0 937,1	0.00C,0	0.00	C.C36,28	0.915,9	0.0C0,0	0.00	0.036,66	0.894,0	0.000,0	0.00
4000	0.035,81	0.864,7	1.000,0	..	0.036,31	0.844,7	0.000,0	0.00	0.C36,86	0.827,1	0.000,0	0.00	0.037,34	0.809,4	0.000,0	0.00
3500	C.036,35	0.768,0	1.000,0	..	C.C36,88	0.750,8	0 000,0	0.00	C.037,51	C.736,5	0.000,0	0.00	0.038,10	0.722,5	0.C00,C	0.00
3000	0.036,90	0.668,2	1.000,0	..	0.037,59	0.655,8	0.000,0	0.C0	0.038,33	0.645,1	0.000,0	0.C0	0.039,04	0.634,6	0.000 0	0.00
2750	0.037,24	0.618,2	1.000,0	..	0.038,02	0.608,1	0.000,0	C.00	0.038,82	0.598,8	0.000,0	0.C0	0.039,59	0.590,0	0.000,C	0.00
2500	0.037,64	0.568,1	1.000,0	..	0.038,47	0.559,3	0.000,0	0.00	C.039,47	0.553,6	0.000,0	0.00	0.040,28	0.545,7	0.000,0	0.00
2400	0.037,78	0.547,4	1.0C0,0	..	0.038,69	0.54C,0	0.000,0	0.00	0.039,70	0.534,5	0.000,0	0.00	0.040,59	0.527,9	0.000,0	0.00
2300	0.037,98	0.527,4	1.000,0	..	0.038,95	0.521,0	C.CCO,0	0.0C	0.039,95	0.515,5	0.000,0	0.00	0.040,90	0.509,8	0.000,0	0.00
2200	0.038,13	0.506.4	1.000,0	..	0.039,21	0.501,7	0.000,0	0.00	0.040,20	0.496,2	0.000,0	0.00	C.041,28	0.492,1	0.C00,0	0.00
2100	0 C38,33	0.485 9	1.000,0	..	C.039,46	0.481,9	0.000,0	0.00	0.040,52	C.477,4	0.000,0	0.00	0.041,66	0.474,0	0.000,0	0.00
2000	0.C38,55	0.465,4	1.C00,0	..	0.039,77	0.462.6	0 000,0	0.00	0.040,80	0.457,8	0.000,0	0 00	0.042,11	0.456,4	0.0CC,0	0.00
1900	C.038,73	0.444,2	1.C00,0	..	0 040,01	0.442,1	0.C0C,0	0.00	0.041,16	0.438,8	0.C0C,0	0 0C	0.042,62	0.438,8	0.00C,0	0.00
1800	0.038,91	0.422,8	1.000,0	..	0 040,28	0.421,6	0.000,C	C.00	0.041,75	0.421,6	C.000,0	0 00	0.043,23	0.421,6	0.040,9	0.95
1700	0.039,06	0.400,9	1.000,0	..	0.04C,48	C.400,2	0.000,0	0.00	C.042,21	0.402,6	0.CC0,0	0.0C	0.044,68	0.411,6	0.260,7	6.26
1600	C.039,26	0.379,2	1.000,0	..	0.040,76	0.379,2	C.CC0,0	0.00	0.042,83	0.384,5	0.079,1	1.82	C.047,48	0.411,6	0.344,1	8.78
1500	0.039,41	0.356,8	1.000,C	..	0.041,23	0.359.7	C.000,0	0.0C	0 043,73	0.368,0	0.346,8	8.15	0.051,76	0.420,7	0.346,2	9.63
1400	C.039,46	0.333,5	1.000,0	..	0.041,37	0.336,8	0.011,2	0.25	0.C47,98	0.376,8	0.415,8	10 72	0.057,90	0.439,2	0.315 6	9.82
1300	0.039,61	0.310,9	1.000,0	..	0.C41,59	0.314,4	0.383,5	8.57	0.054,09	0.394,5	0.378,1	1C.99	0.065,74	0.463,1	C.270,1	9.54
1200	0.039,92	0.289,2	1.000,0	..	0.047,44	0.331,1	0.510,0	13.0C	C.062,63	0.421,6	0.313,5	10.55	0.075,10	0.488,3	0.223,5	9.02
1100	0.042,33	0.281,1	0.751,8	17.1C	0.058,24	0.372,6	0.378,6	11.85	0.C73,65	C.454,5	C.246,6	9.76	0.086,60	0.516,2	0.179,9	8.37
1000	C.054,06	0.326,3	0.479,9	13.94	C.071,52	0 415,9	C.272,7	10.48	0 C87,04	0.488,3	0.189,2	8.85	0.100,7	0.545,5	0 140,9	7.62
900	C.070,50	0.383,0	0.308,3	11.68	0.087,56	0.458,3	0.194,5	9.15	0.1C3,4	0.522,2	0.141,3	7.85	0 118,4	0.577,4	C.107,5	6.84
800	0 09C,96	0.439,2	0.196,6	9.61	0.108,3	0.5C4,C	0.134,8	7.85	C.125,5	0.563,1	0.101,4	6.84	0.141,2	0.612,2	0.079,8	6.06
600	0.152,8	0.553,4	..	..	0.172,8	0.603,1	..	..	0.193,1	0.650,1	..	..	0.212,3	0.690,3	..	..
400	0.28C,2	0.676,5	..	..	0.306,8	0.713,7	..	..	0.333,5	0.748,4	..	..	0.358,9	0.778,0	..	..
200	0.679,5	0.820,4	..	..	0.723,1	C.841,1	..	..	0.766,8	0.860.4	..	..	0.809,8	0.877,6	..	..
14.4	11.36	0.987,1	..	..	11.80	0.988,6	..	..	12.25	0.990,0	..	..	12.70	0.991,2	..	..
Phase boundary	(1,120)† 0.040,97	0.277,0	1.000.0	22.01	(1.412)‡ 0.041,37	0.339,7	0.000,0	0.00	(1,645)‡ 0.042,56	0.392,8	0.CC0,0	0.00	(1,825)‡ 0.043,02	0.425,4	0.000,0	0.00

Pressure, psia	10 F				40 F				70 F				100 F			
	v	Z	L/F	l:g	v	Z	L/F	l:g	v	Z	L/F	l:g	v	Z	L/F	l:g
5000	0.037,40	0.948,5	0.000,0	0.C0	0.039,15	0.933,3	0.000,0	0.00	0.C41,80	0.940,C	0.C00,0	C.00	0.C44,81	0.953,8	0.000,0	0.00
4500	0.C38,C9	0.869,5	0.000,0	0.00	0.040,12	0.860,9	0.000,0	C.00	0.043,03	0.870,9	0.000,0	0.C0	0.046,41	0.889,0	0.CC0,0	0.00
4000	0.038,93	0.789,9	0.C0C,0	0.00	0.041,28	0.787,3	0.000,0	0.00	C.044,64	0.8C3,2	0.000,0	0.00	0.048,58	0.827,1	0.000,0	0.00
3500	0.C39,93	0.708,9	0.000,0	0.00	0.042,79	0.714,1	0.C00,0	C.C0	0.046,78	0.736,5	0.C0C,0	0.00	0.C51,31	0.764,4	0.000,0	0.00
3000	0.041,38	0.629,8	0.C00,0	0.C0	0.044,80	0.640,8	0.000,C	0.00	0.049,99	0.674,6	C.000,0	0.0C	0.055,40	0.707,5	0.000,0	0.00
2750	0.042,23	0.589,1	0.000,0	0.00	0.046,22	0.606.0	0.000,0	0.00	0.052,17	0.645,3	0.000,0	C.0C	0.058,85	0.688,9	0.000,0	0.00
2500	0.043,32	0.549,3	0.0C0,0	0.00	0.048,46	0.577,6	0.000,0	0.00	0.055,58	0.625,0	0.000,0	0.00	0.063,79	0.678,9	0.061,3	2.10
2400	0.043,83	0.533,6	0.00C,0	0.00	0.049,75	0.569,3	0.000,0	0.00	0.057,53	C.621,0	C.C85,7	2.65	0.066,26	0.677,0	0.082,6	2.94
2300	0 044,43	0.518,3	0.000,0	C.00	0.C51,26	0.562,2	0.018,2	0.50	0.059,82	0.618,9	0.124,4	4.00	0.069,05	0.676,0	0.094,9	3.52
2200	C.045,17	0.504,0	0.000,0	0.00	0.053,30	0.559,1	0.148,7	4.26	0.062,70	0.620,5	0.138,6	4.67	0.072,24	0.676,5	0.100,5	3.90
2100	0.046,02	0.490,2	0.000,0	0.00	0.055,91	0.559,8	0.189,7	5.70	0.066,05	0.623,9	0.141,2	5.01	0.075,89	0.678,4	0.100,5	4.10
2000	0.047,45	0.481,4	0.170,6	4.35	0.059,00	0.562,6	0.201,9	6.40	0.069,91	0.628,9	0.139,5	5.24	0.080,16	0.682,5	0.098,2	4.23
1900	0.050,C5	0.482,4	0.254,0	6.83	0.062,69	0.567,9	0.197,1	6.64	0.074,31	0.635,1	0.135,2	5.40	0.085,06	0.687,9	0.094,1	4.30
1800	0.053,35	C.487,1	0.270,7	7.76	C.066,95	0.574,6	0.183,7	6.61	0.079,41	0.642,9	0.127,0	5.42	0.090,66	0.694,6	0.089,3	4.35
1700	0.057,46	0.495,5	0.256,5	7.92	0.072,00	0.583,6	0.168,0	6.50	0.085,30	0.652,2	0.117,2	5.37	0.097,01	0.702,0	0.083,4	4.35
1600	0.062,43	0.506,7	0.233,1	7.82	0.077,91	0.594,3	0.151,4	6.34	0.092,02	0.662,2	0.107,0	5.29	0.104,3	0.710,1	0.077,5	4.34
1500	0.068,37	C.520,2	0.207,7	7.63	0.084,73	C.606,0	0.135,3	6.16	0.C99,85	C.673,6	0.096,5	5.18	0.112,6	0.718,9	0.071,1	4.30
1400	0.075,87	0.538,8	0.181,0	7.38	0.092,78	0.619,3	0.119,3	5.95	0.108,8	0.684,8	0.086,6	5.06	0.122,5	C.730,1	0.064,9	4.27
1300	0.084,78	0.559,1	0.155,4	7.08	0.102,38	0.634,6	0.104,2	5.73	0.119,3	0.697,7	0.076,4	4.90	0.134,1	C.742,0	0.058,7	4.23
1200	0.095,33	0.580,3	0.131,8	6.75	0.113,91	0.651,7	0.089,8	5.50	0.131,9	0.712,0	0.067,0	4.75	0.147,8	0.754,9	0.052,6	4.18
1100	0.108,0	0.602,4	0.110,0	6.38	0.127,90	0.670,8	0.076,5	5.26	0.146,9	0.727,0	0.058,0	4.58	0.164,2	0.768,9	0.046,7	4.12
1000	0.123,5	0.626,2	0.090,4	6.00	0.145,03	0.691,5	0.064,3	5.01	0.165,4	0.744,2	0.049,6	4.41	0.184,1	0.783,7	0.040,6	4.02
900	0.142,9	0.652,2	0.073,2	5.62	0.166,53	0.714,6	0.053,1	4.75	0.188,8	0 764,2	0.041,3	4.19	0.209,0	C.800,6	0.034,4	3.86
800	0.168,2	0.682,5	0.057,5	5.20	0.194,09	0.740,4	0.043,0	4.49	0.218,5	0.786,1	0.034,0	3.98	0.240,6	0.819,2	0.028,5	3.68
600	0.246,6	0.750,6	..	..	0.279,1	0.798,5	..	..	C.309,5	0.835,2	..	..	C.337,3	0.861,4	..	..
400	0.406,7	0.825,2	..	..	0.452,6	0.863,3	..	..	0.494,6	0.889,9	..	..	0.532,3	0.906,4	..	..
200	0.893,9	0.906,9	..	..	0.974,2	0.929,0	..	..	1.049	C.943,3	..	..	1.120	C.953,1	..	..
14.4	13.60	0.993,3	..	..	14.49	0.994,8	..	..	15.38	0.995,9	..	..	16.26	0.996,7	..	..
Phase boundary	(2,C94)‡ 0.046,11	0.489,8	0.000,0	0.00	(2,305)‡ 0.051,20	0.562,6	C.0C0,0	0.00	(2,477)‡ 0.056,02	0.624,1	0.0C0,0	0.00	(2,580)‡ 0.062,01	0.681,0	0.000,0	0.00

( )† = Phase boundary pressure at bubble point, psia.
( )‡ = Phase boundary pressure at dew point, psia.

$\frac{Pv}{ZT} = b = 0.419,8$ $\quad (L/F) = \frac{0.001,861(l:g)}{v}$ Critical temperature = −63.2 F. Critical pressure = 1,156 psia. Critical specific volume = 0.041,01 cu ft per lb.

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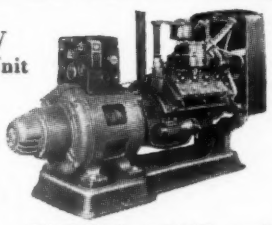

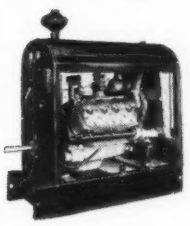

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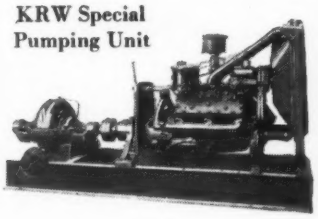

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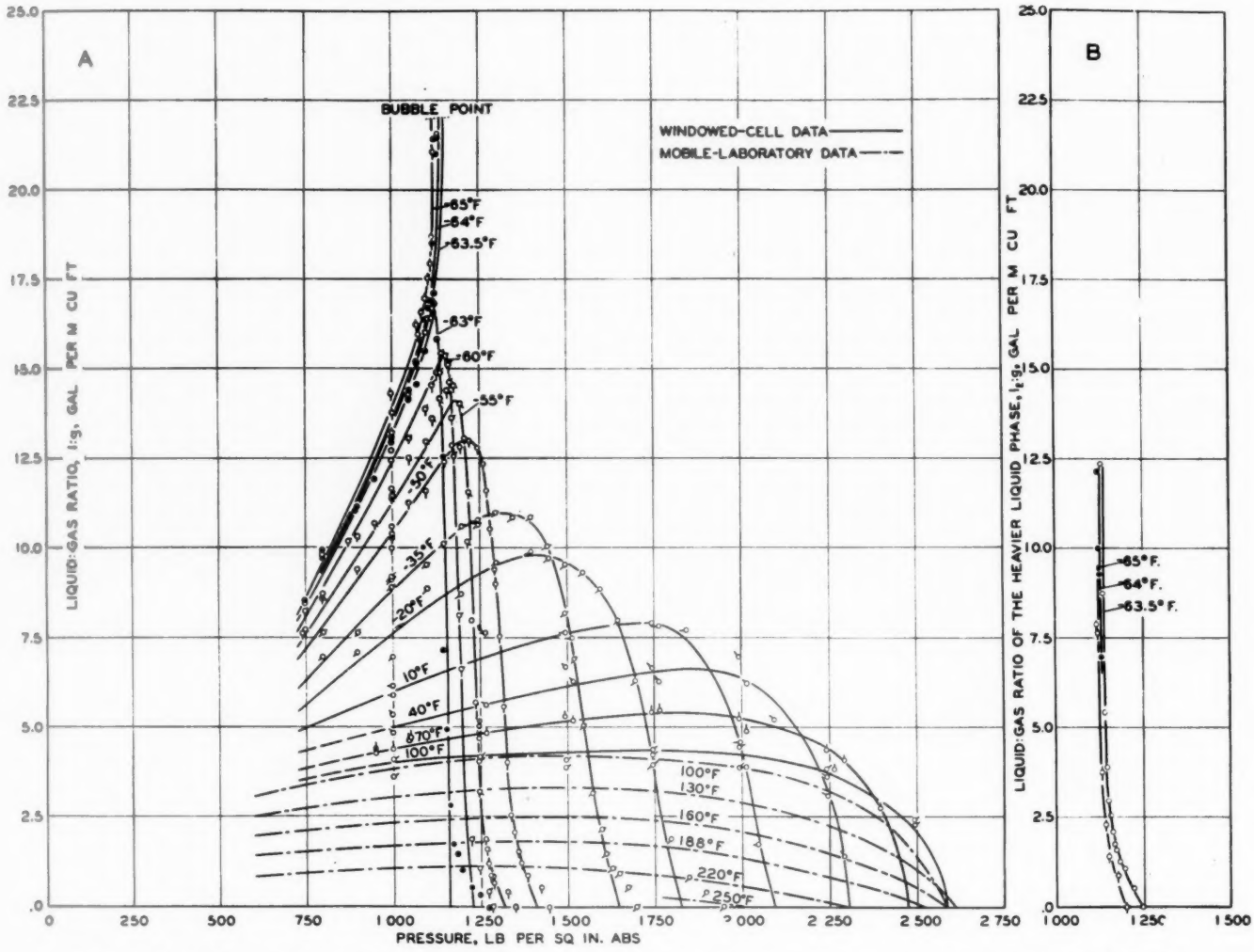


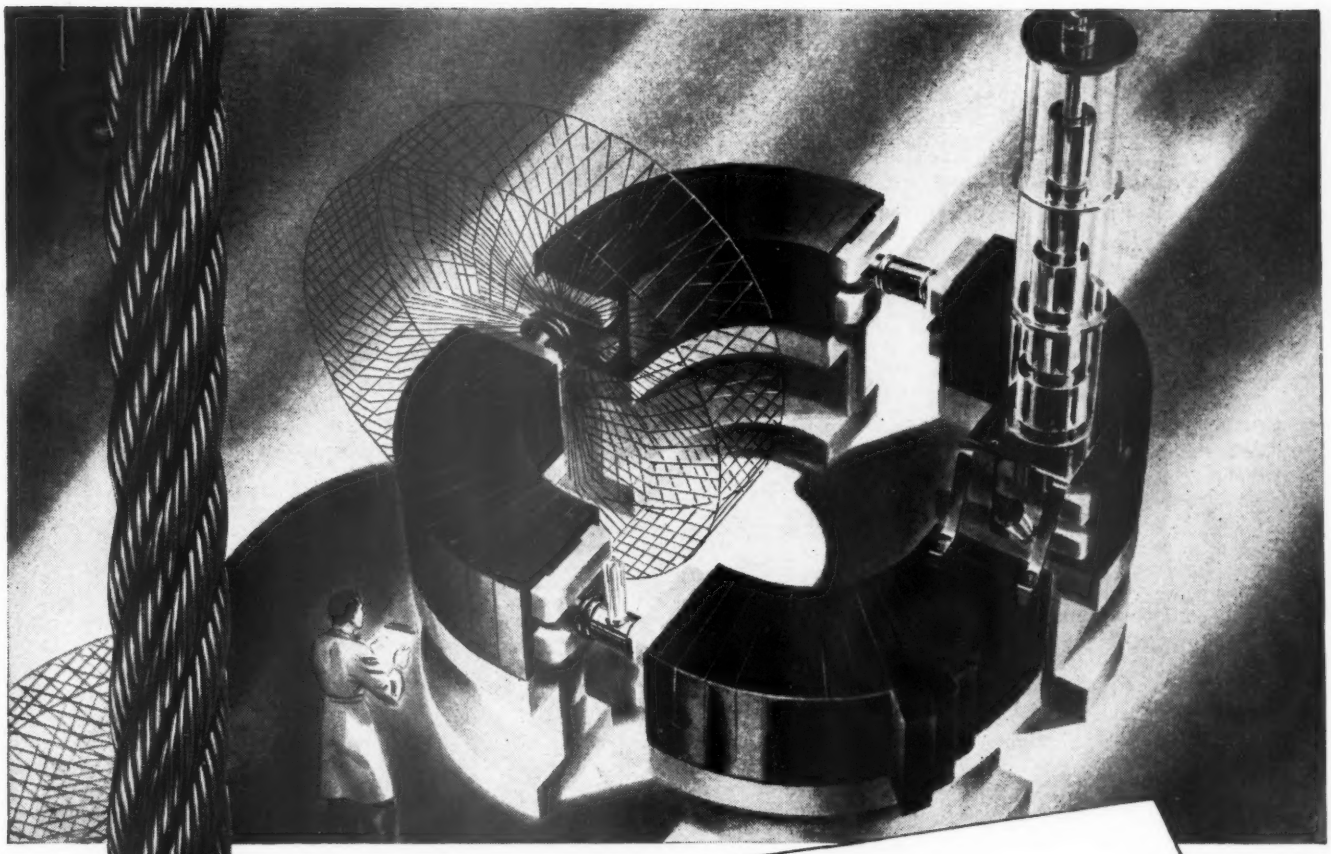
FIG. 4. Liquid-gas ratios of the fluid containing 72.47 mass per cent separator gas: A, measure of all liquid; B, measurement of only the heavier of two liquids coexisting at temperatures less than the critical temperature.

approximately 8 per cent of the volume of the mixture. In computing the volume of the dissolved gas, equilibrium factors developed from vapor pressures of paraffin hydrocarbons reported by Smith[11] were used. Values of the factors used with the composition data shown in Table 1 were as follows: Carbon dioxide, nitrogen and methane combined, 249; ethane, 39.9; propane, 8.66; isobutane, 3.46; normal butane, 2.18; isopentane, 0.799; normal pentane, 0.591; hexanes, 0.168; heptanes, 0.051; octanes, 0.015; nonanes, 0.005,0; decanes, 0.001,6; undecanes, 0.000,5; and dodecanes, and heavier, 0.000,2.

It is estimated that the maximum uncertainty in the value of the constant b, which could result from this computation of the volume of the liberated gas and extrapolation of the value of the function Pv/T to zero pressure, is less than 0.6 per cent.

● **Liquid-gas ratios of the flowing fluid at low temperatures.** The mixture containing 72.47 mass per cent separator gas was in a single phase at pressures above 2610 psia, irrespective of the temperature. When the pressure was lowered at constant temperatures higher than the critical temperature of the mixture, a liquid appeared in the cell; the pressures at which liquid first made its appearance were dew-point pressures. The volumes of liquid that accumulated in the cell when the pressures were below the dewpoints at given temperatures are presented graphically in Fig. 4, section A, on a liquid-gas ratio basis. These liquid volumes were measured to obtain the liquid-gas ratio data at the same time that total volumes of the fluid were measured to obtain information on its compressibility. The unit of liquid-gas ratio measurement involves the quantity of separator gas that would be contained in a volume of 1000 cu ft at a pressure of 14.4 psia and a temperature of 60 F. The liquid volumes are measured at the pressure and temperature of the cell. Also shown in Fig. 4, section A, are liquid-gas ratios for the temperature range 100 to 250 F measured in the field with portable equipment[10] (Fig. 8). The isotherm determined by means of the windowed cell at minus 65F is at a temperature lower than the critical temperature of the fluid and therefore was low enough to permit total liquefaction of the fluid when the pressure was 1120 psia. The maximum temperature used in operating the portable equipment was 250 F. It is estimated that at 276 F (cricondentherm temperature) the fluid would be entirely in a gas phase, regardless of the magnitude of the pressure.

The procedure used in determining the critical temperature of the fluid by means of the windowed cell was to obtain the liquid-gas ratio datum at the lowest pressure first and then to increase the pressure of operation, step by step, at constant temperature until the phase-boundary pressure was reached. If the temperature of operation was higher than the critical temperature, the volume of liquid in the cell increased to a maximum and then decreased until it disappeared entirely. The isotherm of liquid-gas ratio values at a temperature of minus 50 F is an example. The pressure (1412 psia) at which the liquid phase disappeared at a temperature of minus 50 F is a dewpoint pressure of the fluid. If the temperature of operation was lower than the critical temperature, the volume of the liquid phase in the cell increased



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continuously with increasing pressures until finally all the gas had been liquefied and liquid entirely filled the space in the cell over the amalgam. An example of this phenomenon is the isotherm of liquid-gas ratio values at minus 65 F. At that temperature, the pressure (1120 psia) at which the fluid was totally condensed is a bubble-point pressure. It will be shown later in this report that dew-point and bubble-point pressures, when plotted as a function of temperature, lie on a smooth curve that includes the critical pressure at the critical temperature.

Assuming, for example, that only isotherms at temperatures of minus 50 and minus 65 F were available—their configurations indicating that the first was above and the second below the unknown critical temperature — the next step would be to operate the cell at an intermediate temperature to determine from the shape of the obtained isotherm if the third temperature of operation were above or below the critical temperature. Proceeding in this manner, the difference between temperatures known to be above and below the critical temperature can be reduced to the desired figure of uncertainty. In this investigation it was the practice to reduce the figure of uncertainty to 0.5F. With reference to section A of Fig. 4, a bubble point was found by means of the isotherm at a temperature of minus 63.5 F, and a dewpoint was found by means of the isotherm at minus 63 F. In the judgment of the operator of the cell, the critical temperature was nearer the higher of the two temperatures and was decided to be minus 63.2 F. The critical pressure (1156 psia) was the pressure at this temperature on a smooth phase-boundary curve.

At temperatures and pressures in the phase-relation region of the critical state, the fluid became red or amber colored in a manner similar to that reported by Brown (12, p. 55). Only slight changes in the pressure or temperature of the fluid were necessary to cause considerable change in the volume of the liquid in the cell; the colors of the coexisting gas and liquid phases also were sensitive to pressure and temperature change and the difference in the intensity of the colors tended to disappear as the critical state was approached. The color changes frequently were helpful to the operator of the cell while adjusting the phases to a state of equilibrium, but at times the color was so intense that only a small amount of light passed through the cell windows so that it was difficult to make the desired observations.

Although the critical state of a given fluid can be defined in terms of pressure and temperature, the operator of the cell would not have means of recognizing and identifying the critical state if the pressure and temperature of the fluid should, by chance, be adjusted exactly to the critical temperature and pressure. Only a uniform color would appear through the windows, and no meniscus would be present between the phases although the slightest lowering

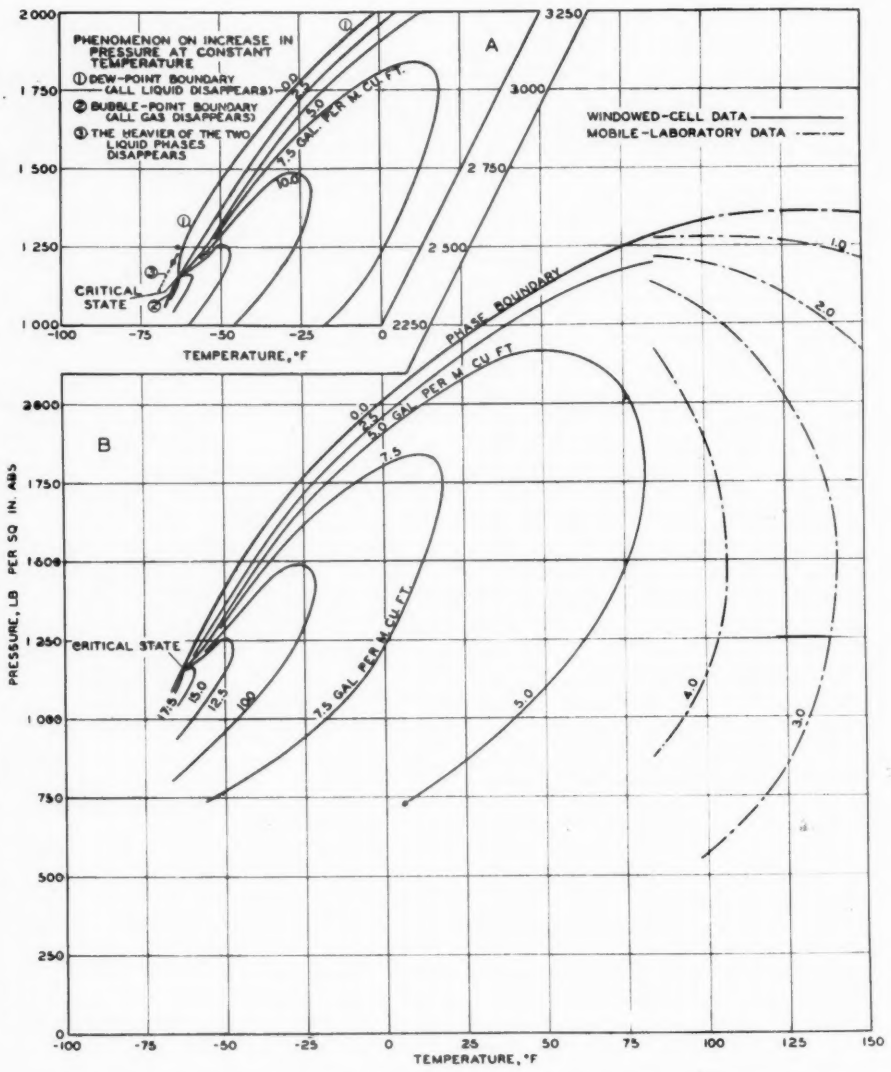

FIG. 5. Phase relations of the fluid containing 72.47 mass per cent separator gas.

of pressure or increase in temperature could cause coexistent gas and liquid phases to form. On the basis of the classical conception of the critical state it is a phase-boundary state of homogeneity, and as the pressure and temperature of a fluid existing in multiple phases approach the value of the critical pressure and temperature, the properties of coexisting phases become more and more alike and approach the values of properties of the fluid in the homogeneous critical state. As a result, the operator of the windowed cell must measure liquid-gas ratios at temperatures and pressures approaching critical temperatures and pressures to identify and determine the critical states of gas-condensate mixtures.

The results of recent investigations of the properties of certain pure components have indicated that at the critical state a discontinuity in the values of properties can prevail. Maass (13, p. 27), in summarizing the results of a series of investigations of the difference in densities measured in fluid columns at temperatures just above the critical temperature (temperature at which a gas-liquid meniscus disappeared on heating), suggested the generality. "what has been called the critical temperature is the temperature at which the normal density of a liquid has decreased to a point beyond which structure rapidly diminishes." One of the sets of results which led to this generalization was the experimental information obtained by Winkler and Maass[14] on propylene. The density of propylene contained in a vertical glass tube was measured in the gas and liquid phases at temperatures below the critical temperature and at the same positions in the tube after the temperature was increased and the meniscus disappeared. Differences in the density at the two positions, which could not be accounted for by effects of gravitation, tended to decrease with rise in temperature but were measurable at temperatures up to 18 F above the critical temperature. The results were reproducible quantitatively, and constant strirring or temperature fluctuations of the order of 0.04 F did not alter the density differ-

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ences during a 6-hr observation period. Harrison and Mayer[15], using methods of statistical mechanics in a theoretical treatment of the problem, obtained results in substantial agreement with the experimental findings of Maass and his coworkers. Briefly, the discontinuity and lack of uniformity observed at the critical state are believed to be due to an arrangement of the molecules in the liquid phase that prevails after the meniscus between the gas and liquid phase disappears.

The phenomenon of density differences between the levels of the fluid at the critical state may have prevailed in hydrocarbon fluids studied in the windowed cell. It does not seem likely, however, that the appearance in one of the fluids at temperatures below the critical temperature of two liquid phases with a meniscus between them can be accounted for by the phenomenon of density differences observed by Maass. For the purpose of this report, it is assumed that the critical state is a phase-boundary state of apparent homogeneity characterized by the absence of a meniscus or other indication of coexistent phases.

● **Multiple phases prevailing at low temperatures.** While readings were being taken of meniscus levels in the cell, small bodies having the profile of a solid phase sometimes partly obscured the passage of light through the windows. As the samples of separator liquid and gas used in preparing the mixtures were not dehydrated, the solid material observed between the windows may have been clusters of hydrocarbon hydrate ice [16, p. 28] floating on the mercury in the cell.

During the investigation of the phase relations of the mixture containing 72.47 mass per cent separator gas, it was discovered that two liquid phases appeared to be present in the cell at temperatures below the critical temperature. The two liquid phases had a clearly defined meniscus between them and in color were different shades of amber. The volumes of both liquids depended upon the temperature and pressure in the cell, and prolonged rocking of the cell did not affect the volumes once phase equilibrium was established. The liquid-gas ratios, l_2:g, of the heavier of the two phases are reported in section B of Fig. 4. The liquid-gas ratios at the three temperatures, minus 65 F, minus 64 F, and minus 63.5 F, reported in section A, Fig. 4, are for the total volumes of both the liquids in the cell.

The relation between the volumes of the two liquid phases and the pressure on the fluid is illustrated by the isotherms in sections A and B of Fig. 4 at a temperature of minius 63.5 F. At a pressure of 1140 psia the position of the gas-liquid meniscus of the supernatant liquid phase indicated that the space over the amalgam in the cell was nearly full of liquid and that the liquid-gas ratio was 18.5 gal of liquid per M cu ft of separator gas. The meniscus between the liquid phases indicated that the heavier liquid was present in the cell in a liquid-gas ratio of 7.0 gal per M cu ft. With application of more pressure the fluid was completely liquefied at a pressure of 1150 psia. The volume of the heavier liquid phase decreased with increasing pressure but, at the bubble-point pressure, the liquid-gas ratio was 3.0 gal per M cu ft. As the liquid phases filling the cell were compressed further, the volume of the heavier liquid phase continued to decrease and finally the second liquid phase dis-

FIG. 6. Relative volume of the liquid phase of the fluid containing 72.47 mass per cent separator gas: A, measurement of all liquid; B, measurement of only the heavier of two liquids coexisting at temperatures less than the critical temperature.

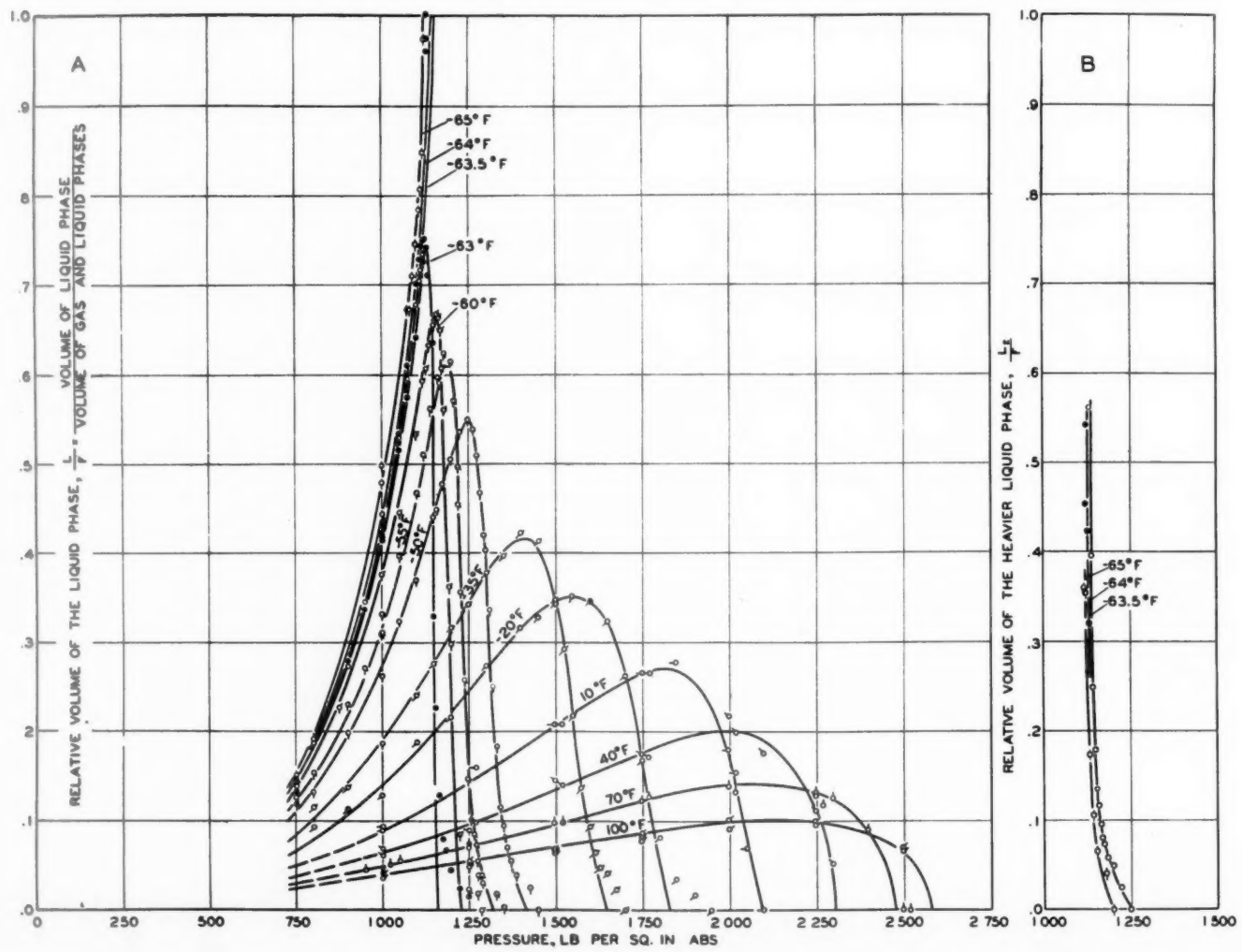

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TABLE 3. Properties of the separator gas at indicated temperatures and pressures.

Pressure, psia	−65 F				−50 F				−35 F				−20 F			
	v	Z	L/F	l:g	v	Z	L/F	l:g	v	Z	L/F	l:g	v	Z	L/F	l:g
5000	0.042,03	0.997,9	1.000,0	..	0.041,19	0.942,1	1.000,0	..	0.042,08	0.928,4	0.000,0	0.00	0.043,34	0.923,7	0.000,0	0.00
4500	0.042,56	0.909,5	1.000,0	..	0.041,92	0.863,0	1.000,0	..	0.043,06	0.855,0	0.000,0	0.00	0.044,45	0.852,5	0.000,0	0.00
4000	0.043,11	0.818,8	1.000,0	..	0.042,79	0.783,0	1.000,0	..	0.044,18	0.779,8	0.000,0	0.00	0.045,68	0.778,9	0.000,0	0.00
3500	0.043,61	0.724,8	1.000,0	..	0.043,80	0.701,3	1.000,0	..	0.045,49	0.702,6	0.000,0	0.00	0.047,30	0.705,6	0.000,0	0.00
3000	0.044,14	0.628,8	1.000,0	..	0.045,03	0.618,0	1.000,0	..	0.047,04	0.622,8	0.000,0	0.00	0.049,39	0.631,6	0.000,0	0.00
2750	0.044,44	0.580,3	1.000,0	..	0.045,76	0.575,6	1.000,0	..	0.048,02	0.582,7	0.000,0	0.00	0.050,74	0.594,7	0.000,0	0.00
2500	0.044,84	0.532,3	1.000,0	..	0.046,73	0.534,4	1.000,0	..	0.049,22	0.543,0	0.000,0	0.00	0.052,40	0.558,4	0.000,0	0.00
2250	0.045,40	0.485,1	1.000,0	..	0.047,88	0.492,8	1.000,0	..	0.050,76	0.564,0	0.000,0	0.00	0.054,51	0.522,8	0.000,0	0.00
2000	0.046,20	0.438,8	1.000,0	..	0.049,17	0.449,9	1.000,0	..	0.052,61	0.464,3	0.000,0	0.00	0.057,33	0.488,7	0.000,0	0.00
1750	0.047,31	0.393,1	1.000,0	..	0.050,88	0.407,3	1.000,0	..	0.055,18	0.426,1	0.000,0	0.00	0.061,70	0.460,2	0.000,0	0.00
1500	0.049,06	0.349,4	1.000,0	..	0.053,35	0.366,1	1.000,0	..	0.059,36	0.392,9	0.000,0	0.00	0.071,10	0.454,6	0.000,0	0.00
1300	0.051,06	0.315,2	1.000,0	..	0.056,81	0.337,8	1.000,0	..	0.066,30	0.380,4	0.000,0	0.00	0.085,48	0.473,7	0.073,3	2.44
1200	0.052,28	0.297,9	1.000,0	..	0.059,73	0.327,9	1.000,0	..	0.077,49	0.410,3	0.170,3	5.14	0.099,9	0.510,8	0.095,1	3.70
1100	0.053,81	0.281,0	1.000,0	..	0.070,00	0.352,2	0.343,0	9.35	0.095,34	0.462,8	0.132,5	4.92	0.117,0	0.548,6	0.076,2	3.47
1000	0.059,98	0.284,8	0.706,4	16.50	0.091,75	0.419,7	0.181,9	6.50	0.115,6	0.510,2	0.092,0	4.14	0.137,9	0.587,6	0.057,6	3.09
900	0.088,56	0.378,5	0.240,1	8.28	0.116,5	0.479,7	0.106,9	4.85	0.140,4	0.557,6	0.063,6	3.48	0.163,5	0.627,3	0.042,4	2.70
800	0.120,2	0.456,4	0.125,9	5.89	0.147,6	0.540,4	0.066,4	3.82	0.172,3	0.608,2	0.044,1	2.96	0.195,4	0.666,1	0.030,5	2.32
700	0.157,8	0.524,6	0.074,8	4.60	0.185,6	0.594,3	0.044,8	3.24	0.212,3	0.655,8	0.031,1	2.57	0.237,4	0.708,3	0.021,4	1.98
600	0.208,6	0.594,3	0.047,3	3.84	0.236,6	0.649,4	0.031,0	2.86	0.266,7	0.706,2	0.021,7	2.25	0.293,4	0.750,2	0.015,1	1.72
400	0.385,3	0.731,9	..	..	0.421.9	0.772,0	..	..	0.455,6	0.804,2	..	..	0.487,9	0.831,9	..	..
200	0.912,1	0.866.2	..	..	0.969,9	0.887,4	..	..	1.023	0.902,8	..	..	1.073	0.914,7	..	..
14.4	14.48	0.990,4	..	..	15.06	0.991,8	..	..	15.62	0.992,9	..	..	16.19	0.993,8	..	..
Phase boundary	(1,012)† 0.056,26	0.270,4	1.000,0	21.91	(1,134)† 0.063,43	0.329,0	1.000,0	24.70	(1,245)‡ 0.070,80	0.389,0	0.000,0	0.00	(1,340)‡ 0.081,49	0.465,4	0.000,0	0.00

Pressure, psia	10 F				40 F		70 F		100 F	
	v	Z	L/F	l:g	v	Z	v	Z	v	Z
5000	0.046,19	0.921,5	0.000,0	0.00	0.049,18	0.922,2	0.052,34	0.925,8	0.056,04	0.938,2
4500	0.047,52	0.853,3	0.000,0	0.00	0.050,89	0.858,9	0.054,43	0.866,6	0.058,92	0.887,8
4000	0.049,31	0.787,0	0.000,0	0.00	0.053,03	0.795,6	0.057,45	0.813,0	0.062,83	0.841,5
3500	0.051,44	0.718,4	0.000,0	0.00	0.056,10	0.736,4	0.061,62	0.763,0	0.068,43	0.801,9
3000	0.054,46	0.651.9	0.000,0	0.00	0.060,58	0.681,6	0.068,14	0.723,2	0.076,74	0.770,8
2750	0.056,58	0.620,8	0.000,0	0.00	0.063,98	0.659,9	0.072,85	0.708,8	0.082,31	0.757,9
2500	0.059,28	0.591,3	0.000,0	0.00	0.068,39	0.641,2	0.078,89	0.697,8	0.089,41	0.748,4
2250	0.063,09	0.566,4	0.000,0	0.00	0.074,29	0.626,9	0.086,90	0.691,8	0.098,96	0.745,5
2000	0.068,44	0.546,2	0.000,0	0.00	0.082,78	0.620,9	0.097,95	0.693,1	0.112,4	0.752,5
1750	0.077,34	0.540,0	0.000,0	0.00	0.095,61	0.627,5	0.113,9	0.705,4	0.131,0	0.767,5
1500	0.093,85	0.561,7	0.000,0	0.00	0.116,5	0.655,4	0.137,5	0.728,7	0.157,1	0.789,0
1300	0.115,6	0.599,8	0.030,2	1.36	0.140,9	0.686,9	0.164,2	0.755,1	0.186,0	0.809,8
1200	0.130,4	0.624,3	0.034,1	1.73	0.156,7	0.705,3	0.181,5	0.770,5	0.204,4	0.821,2
1100	0.148,9	0.653,4	0.031,4	1.82	0.175,8	0.725,1	0.202,2	0.786,8	0.226,2	0.833,2
1000	0.171,0	0.682,4	0.026,1	1.74	0.199,1	0.746,9	0.227,2	0.803,8	0.252,4	0.845,0
900	0.198,0	0.710,9	0.019,8	1.53	0.228,1	0.769,9	0.258,2	0.822,2	0.284,9	0.858,5
800	0.232,2	0.741,2	0.013,6	1.23	0.264,8	0.794,4	0.297,2	0.841,3	0.326,0	0.873,1
700	0.276,5	0.772,3	0.009,1	0.98	0.312,3	0.819,9	0.347,6	0.860,8	0.378,6	0.887,4
600	0.335,7	0.803,6	0.006,1	0.80	0.375,4	0.844,8	0.414,5	0.879,9	0.449,2	0.902,4
400	0.542,8	0.866,4	..	..	0.596,7	0.895,2	0.649,8	0.919,6	0.696,7	0.933,1
200	1.168	0.932,4	..	..	1.261	0.945,8	1.356	0.959,7	1.442	0.965,7
14.4	17.32	0.995,2	..	..	18.45	0.996,3	19.57	0.997,2	20.69	0.997,6
Phase boundary	(1,386)‡ 0.105,1	0.581,4	0.000,0	0.00	.. ..	..	.. ..	..	.. ..	..

( )† = Phase boundary pressure at bubble point, psia.

( )‡ = Phase boundary pressure at dew point, psia.

$\frac{Pv}{ZT} = b = 0.533,7$ $\quad (L/F) = \frac{0.002,568\,(l:g)}{v}$

Critical temperature = −45.2 F. Critical pressure = 1176 psia Critical specific volume = 0.065,60 cu ft per lb.

appeared entirely at a pressure of 1248 psia.

Two liquid phases did not appear at operating temperatures above the critical temperature, nor were they observed in the work done on other mixtures at temperatures below or above the respective critical temperatures. It would have been difficult to obtain samples of the coexistent liquids and no attempt was made to determine their compositions. It is possible that additional information on this subject will be obtained when flowing fluids sampled from other reservoirs are studied.

In this connection, Kuenen and Robson[17] in 1899 described four possible composition - temperature relationships for coexistent liquid phases. The examples of such relationships mentioned by the authors and other examples discovered by investigators working in later years usually are two-component systems involving two liquid phases, the composition of which has been determined at different temperatures under atmospheric pressure. Each of the relationships discussed by Kuenen and Robson take into consideration the composition of the vapor phase, the liquid phases and the critical solution temperature at which two or more of the phases become identical in composition and are mutually soluble. One of the relationships required that the vapor phase and the two liquid phases all attain the same composition at the critical solution temperature. For this relationship, the phase state at the critical solution temperature meets all the requirements of the definition of the critical state for natural hydrocarbon mixtures under pressure. Without extensive experimental data on the gas-condensate fluid studied for temperatures well below the critical temperature it cannot be assumed that the concepts expressed by Kuenen and Robson apply to the two-liquid-phase phenomenon observed. The phenomenon may have practical significance, however, and it will be helpful if the concepts of the phase relations of partly miscible liquids eventually are found applicable to gas-condensate fluids at liquefaction temperatures.

● **The critical state and phase relations of the flowing fluid.** Another graphical presentation of the liquid-gas ratio data of Fig. 4 is shown in section B of Fig. 5 where the coordinate of pressure is retained, and temperature is the other variable. Liquid-gas ratios appear as parameters converging at the point on the phase-boundary curve identified as the critical state. A part of the data obtained in the field with mobile equipment at temperatures above 85 F is included in the figure. The maximum pressure of the phase boundary (cricondenbar) is 2610 psia at 136 F. It is estimated that the phase-boundary curve encloses a multiple-phase-state region that extends to temperatures as high as 276 F. Although phase-boundary pressures and liquid-gas ratios measured by means of the windowed cell in the laboratory and by means of the mobile laboratory in the field are not in exact agreement in the temperature region 85 to 100 F, where they overlap, the two methods of investigation have substantiated each other satisfactorily.

Bubble-point pressures can be determined by means of the windowed cell with greater accuracy than dew-point pressures; and, in evaluating a smooth phase-boundary curve for the mixture, the bubble-point pressure measurements at temperatures of minus 65, minus 64, and minus 63.5 F were given greater weight than dewpoint pressures measurements at higher temperatures. The critical pressure of 1156 psia is the phase boundary pressure at the critical temperature, which is minus 63.2 F. The critical pressure, therefore, was determined largely by the measurement of the bubble-point pressures. Phase-boundary pressures and other significant data illustrated in section B of Fig. 5 are given in Table 2.

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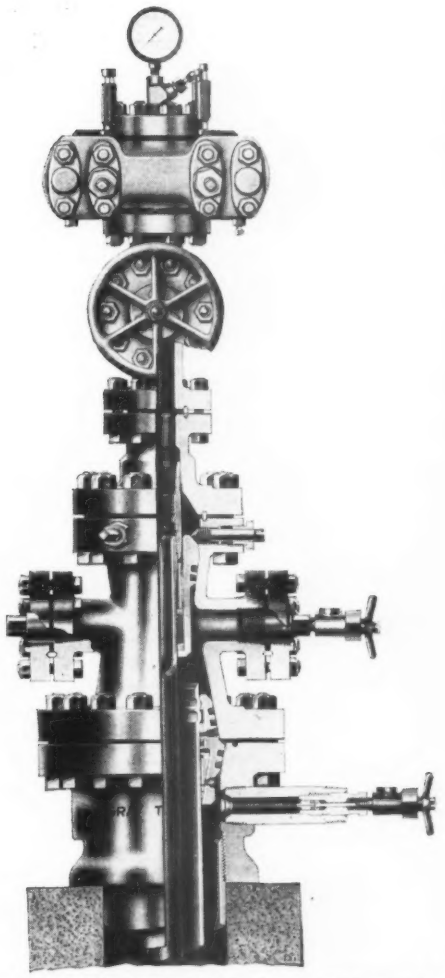

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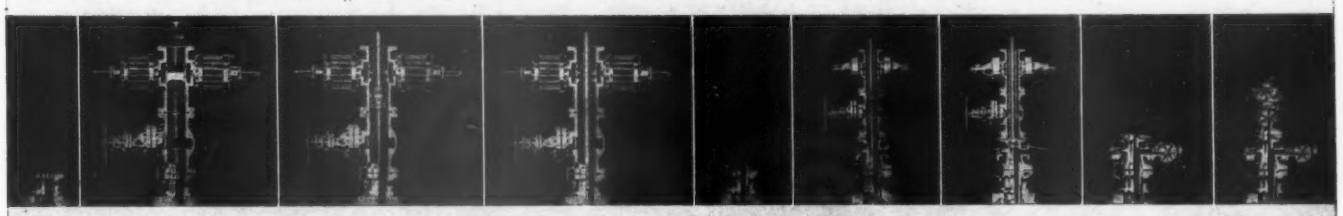

In section A of Fig. 5, a portion of the phase-relations figure, including the critical state, has been reproduced to show a possible configuration of the phase boundary when the values of the dew-point pressures measured at low temperatures are accepted. The pressures of disappearance of the heavier of the two liquid phases coexistent at temperatures lower than the critical temperature also are considered. Data points are shown for two such pressure measurements at minus 63.5 F and minus 65 F. The dew-point pressures indicated by curve *1* in section A are greater than the dew-point pressures at corresponding temperatures shown by the phase-boundary curve in section B. The difference in the pressures indicated by the two curves is negligible at O F but increases to approximately 70 psi at minus 60 F. The addition of pressure required to cause the heavier of the coexistent liquid phases to disappear (curve *3*) starting with the sample at the pressure of the bubble point (curve *2*) was approximately 80 psi. Curve *3* therefore appears to be an extension of curve *1*.

The critical state indicated in section A is at a pressure of 1156 psia and a temperature of minus 63.2 F, the same as shown in section B. There is no evidence to indicate that some other value for the critical temperature should be considered. If curve *1* of measurements of dew-point pressures and curve *3* were used to determine the critical pressure, the value would be approximately 80 psi greater than the accepted value.

The phase-boundary curve drawn in section A (curves *1* and *2*) is discontinuous at the critical state. This configuration may be possible but a review of the literature has not yielded a precedent for such interpretation. Also, it seems possible that data could be obtained, by use of a special apparatus and technique, to show that, as the temperature approaches the critical temperature, curve *3* changes direction and passes through the pressure-temperature point of the indicated critical state.

The freezing point of the thallium amalgam available for use in the windowed cell was not low enough to permit experimentation at temperatures lower than minus 65 F. Before interpretations of the kind illustrated in section A can be accepted or completely rejected, phase-relations data on similar gas-condensate mixtures should be obtained for temperatures 30F or more lower than the critical temperatures of the mixtures. Without such information, the phase-boundary configuration shown in section B is believed to be the most reliable interpretation now possible of the data available on the mixture studied. The accepted value of the critical pressure is based on the measurements of bubble-point pressures, which were more reliable than the measurements of dew-point pressures. The phase relations at the accepted pressure and temperature of the critical state were in strict conformity with the definitions of the critical state. The fluid was apparently homogeneous, all evidences of gas-liquid and liquid-liquid menisci having disappeared as the phase-boundary pressure and temperature were approached.

FIG. 7. Specific volume data for the separator gas.

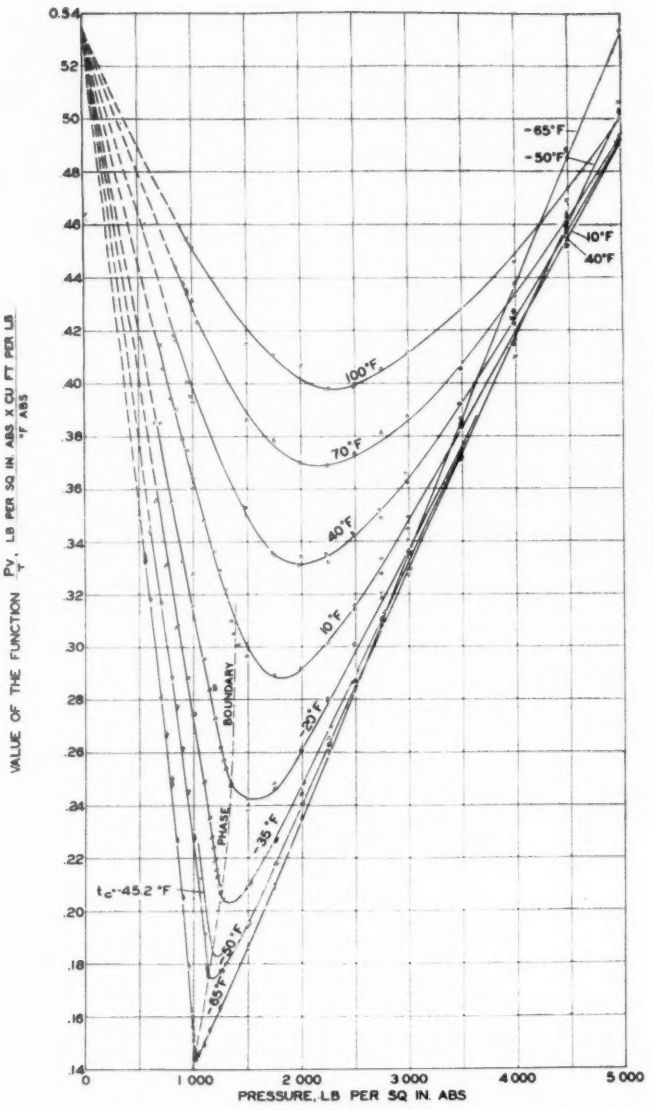

TABLE 4. Properties of the mixture containing 84.04 mass per cent separator gas.

Pressure, psia	—60 F				—55 F				—50 F			
	v	Z	L/F	l:g	v	Z	L/F	l:g	v	Z	L/F	l:g
1200	0.046,52	0.298,2	1.000,0	..	0.048,96	0.309,9	0.522,3	11.85	0.053,72	0.336,0	0.442,7	11.02
1100	0.053,76	0.315,9	0.513,8	12.80	0.061,06	0.354,3	0.387,4	10 96	0.067,10	0.384,6	0.310,7	9.66
1000	0.069,69	0.372,2	0.311,8	10.07	0.077,36	0.408,1	0.248,8	8.92	0.083,31	0.434,2	0.203,8	7.87
900	0.089,33	0.429,4	0.196,9	8.15	0.096,74	0.459,3	0.162,1	7.26	0.103,3	0.484,5	0.135,8	6.50
800	0.113,8	0.486,2	0.128,2	6.76	0.121,2	0.511,4	0.109,2	6.13	0.128,0	0.533,6	0.093,9	5.57
700	0.144,9	0.541,7	0.088,9	5.97	0.152,8	0.564,4	0.076,8	5.44	0.159,7	0.582,7	0.067,5	5.00
600	0.187,2	0.599,8	0.063,9	5.54	0.195,0	0.617,3	0.056,2	5.08	0.202,3	0.632,7	0.049,6	4.65
400	0.334,1	0.713,8	..	..	0.343,9	0.725,7	..	..	0.354,3	0.738,5	..	..
200	0.786,0	0.839,7	..	..	0.802,3	0.846,5	..	..	0.819,0	0.853,6	..	..
14.4	12·85	0.988,5	..	..	13.02	0.989,0	..	..	13.19	0.989,5	..	..
Phase boundary	(1,150)† 0.047,12	0.289,4	1.000,0	21.86	(1,216)‡ 0.048,11	0.308,6	0.000,0	0.00	(1,282)‡ 0.048,85	0.326,4	0.000,0	0.00

( )† = Phase boundary pressure at the bubble point, psia.

( )‡ = Phase boundary pressure at the dew point, psia.

$\frac{Pv}{ZT} = b = 0.468,5$ $\qquad (L/F) = \frac{0.002,158\ (l:g)}{v}$

Critical temperature = —56.3 F.
Critical pressure = 1198 psia.
Critical specific volume = 0.047,94 cu ft per lb.

● **Relative volumes of the liquid phase of the flowing fluid.** The measurements of liquid volumes and their relation to pressure and temperature are shown on a relative volume basis in Fig. 6. The relative volume of the liquid phase, as it applies to the phase state of a fluid, is defined as the ratio of the volume of the liquid phase at a given temperature and pressure to the sums of the volumes of the gas and liquid

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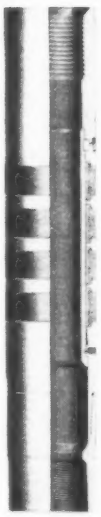

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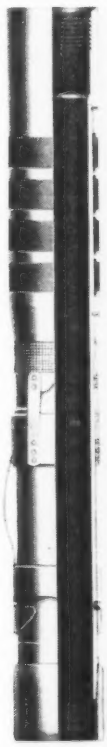

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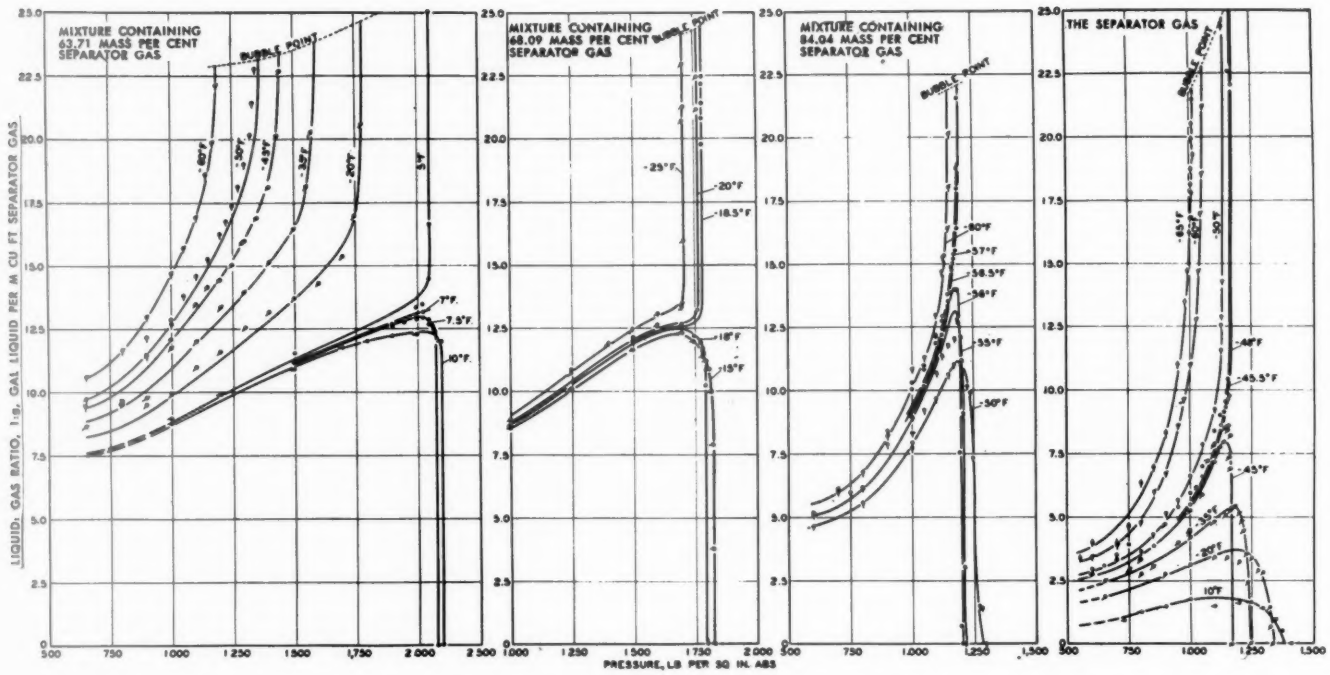
MIXTURE CONTAINING 63.71 MASS PER CENT SEPARATOR GAS
MIXTURE CONTAINING 68.09 MASS PER CENT SEPARATOR GAS
MIXTURE CONTAINING 84.94 MASS PER CENT SEPARATOR GAS
THE SEPARATOR GAS
BUBBLE POINT
LIQUID-GAS RATIO, l:g, GAL LIQUID PER M CU FT SEPARATOR GAS
PRESSURE, LB PER SQ IN. ABS

FIG. 8. Liquid-gas ratios of mixtures of separator liquid and gas combined in indicated mass per cent proportions.

phases at the same pressure and temperature. With reference to Fig. 6, dewpoints of the fluid correspond to zero relative liquid volume, and bubble points correspond to relative liquid volumes of unit value. For some purposes the relative liquid volume concept is more useful than the liquid-gas ratio concept. The relative liquid volume is readily visualized; for example, a relative liquid volume of 0.7 means hydrocarbon liquid filled 0.7 of the space in the cell above the surface of the thallium amalgam. The other 0.3 of the space would be filled with gas. The relative liquid-volume concept is particularly useful in discussions of flow of fluids in reservoirs[18] because the pressure and temperature base for the gas measurement is identical with the reservoir pressure and temperature.

The relative liquid-volume data shown in Fig. 6 are related to the liquid-gas ratio data shown in Fig. 4 and to the specific-volume data shown in Fig. 3 through the formula:

$$(L/F) = \frac{0.001{,}861\ (1:g)}{v} \quad . \ . \ . \quad (2)$$

Where:

(L/F) = relative liquid volume of the liquid phase at the given pressure and temperature,

$(1:g)$ = liquid-gas ratio of the liquid phase at the given pressure and temperature, gal per M cu ft,

v = specific volume of the fluid, cu ft per lb.

The value of the constant (0.001,861) is determined by a conversion factor and the content of separator gas in the mixture as follows: 1/(7.48 gal per cu ft × 71.84 lb mixture per M cu ft gas). The weight of M cu ft of gas at a pressure of 14.4 psia and a temperature of 60F was 1000/19.21 = 52.06 lb.

In the ordinate designations of sections B of Figs. 4 and 6, the symbols $(l_2{:}g)$ and (L_2/F) are used to designate the heavier of the two coexisting liquid phases. Equation (2) also applies to these data.

The tabulated data of Table 2 were taken from the smooth curves of Figs. 3, 4, and 6; as the curves were conformed to satisfy equations 1 and 2, the data in Table 1 satisfy these same equations.

● **P-V-T relations of separator gas.** The specific volume of the separator gas determined in the field by means of a gas balance was 19.21 cu ft per lb at a pressure of 14.4 psia and a temperature of 60 F. The precision uncertainty of this mean specific volume, based on 11 comparisons of the gas with dry air, was 0.02 cu ft per lb. On the basis of this specific-volume measurement, the gas constant b was estimated to have a value of 0.5337.

In the laboratory, the first use of the windowed cell was to determine the compressibility factor of the gas at a pressure of 1000 psia and a temperature of 70 F. This datum was needed for determining the mass of the gas used in preparing the hydrocarbon mixtures studied. The volumes of three gas sam-

TABLE 5. Properties of the mixture containing 68.09 mass per cent separator gas.

Pressure, psia	−25 F				−20 F				−15 F			
	v	Z	L/F	l:g	v	Z	L/F	l:g	v	Z	L/F	l:g
1750	0.041,32	0.415,0	1.000,0	..	0.042,78	0.424,7	0.531,5	13.00	0.044,69	0.438,6	0.467,3	11.94
1700	0.042,34	0.413,0	0.566,8	13.72	0.043,91	0.423,4	0.506,2	12.71	0.045,87	0.437,4	0.466,7	12.24
1600	0.044,87	0.412,0	0.505,6	12.97	0.046,82	0.424,9	0.466,6	12.49	0.049,16	0.441,1	0.430,5	12.10
1500	0.048,50	0.417,4	0.449,0	12.45	0.051,08	0.434,7	0.412,6	12.05	0.053,94	0.453,9	0.377,4	11.64
1400	0.053,89	0.432,9	0.383,6	11.82	0.056,77	0.450,9	0.352,4	11.44	0.059,89	0.470,3	0.322,7	11.05
1300	0.060,81	0.453,6	0.320,7	11.15	0.064,65	0.472,3	0.293,8	10.76	0.067,34	0.491,0	0.269,6	10.38
1200	0.069,46	0.478,3	0.262,9	10.44	0.072,86	0.496,0	0.242,0	10 08	0.076,32	0.513,7	0.223,4	9.75
1100	0.079,89	0.504,2	0.212,8	9.72	0.083,52	0.521,2	0.196,8	9.40	0.087,18	0.537,9	0.182,8	9.11
1000	0.092.74	0.532.2	0.170,9	9.06	0.096,71	0.548,6	0.159,3	8.81	0.100,5	0.563,8	0.148,9	8.56
800	0.129,1	0.592,8	..	..	0.134,7	0.611,5	..	..	0.139,7	0.626,9	..	..
600	0 193,5	0.666,3	..	..	0.201,3	0.685,3	..	..	0.208,5	0.701,7	..	..
400	0.330,3	0.758,1	..	..	0.341,6	0 775,1	..	..	0.352,6	0.791,0	..	..
200	0.749,5	0.860,1	..	..	0.771,1	0.874,8	..	..	0.792,7	0.889,3	..	..
14.4	11.99	0.990,5	..	..	12.13	0.990,9	..	..	12.27	0.991,3	..	..
Phase boundary	(1,704)† 0.042,26	0.413,2	1.000,0	24.15	(1,763)† 0.042,54	0.425,4	1.000,0	24.35	(1,824)‡ 0.043,24	0.442,4	0.000,0	0.00

( )† = Phase boundary pressure at the bubble point, psia.

( )‡ = Phase boundary pressure at the dew point, psia.

$$\frac{Pv}{ZT} = b = 0.401,0 \qquad (L/F) = \frac{0.001,749\ (1:g)}{v}$$

Critical temperature = −18.3 F.
Critical pressure = 1785 psia.
Critical specific volume = 0.042,72 cu ft per lb.

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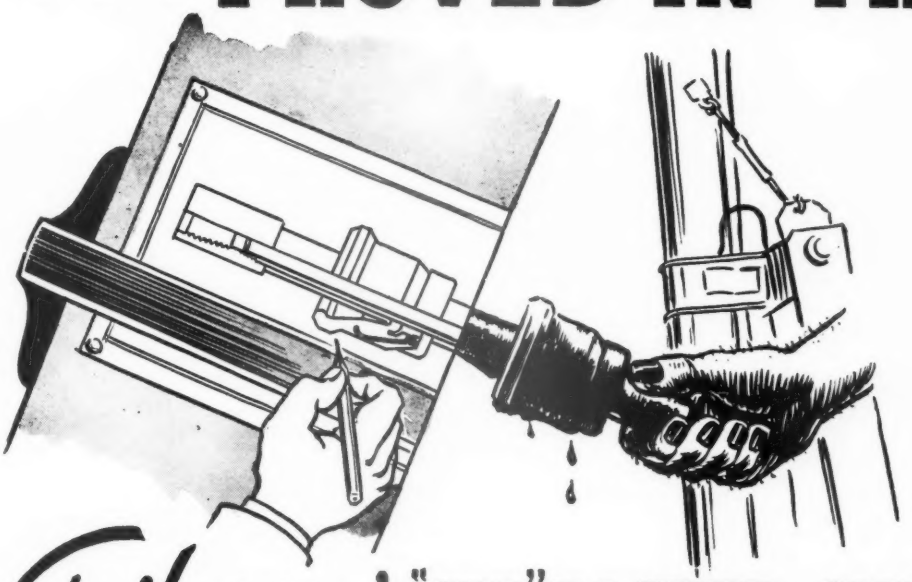

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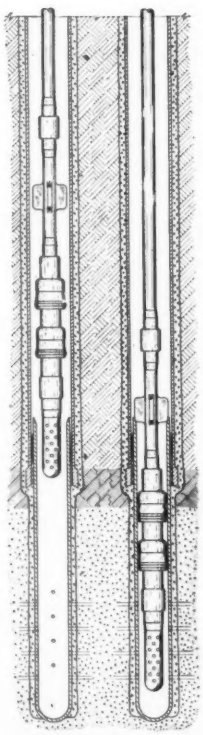

A B

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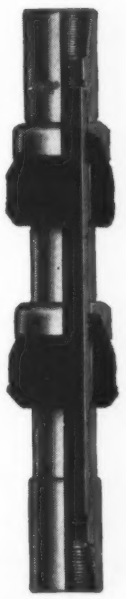

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ples were measured in the cell at the required pressure and temperature and then expanded into a calibrated steel cylinder of such size that the resultant pressure would be less than atmospheric pressure. A baro-buret [8, p. 12], which is a manometric instrument, was used to measure the subatmospheric pressures with an accuracy of 0.1 mm of mercury. The ratios of the values of the function Pv/T at the cell pressure and at atmospheric pressures provided the value of the required compressibility factor Z = 0.8038 shown in Table 3 for 1000 psia and 70 F. The measured value is subject to a precision uncertainty of 0.5 per cent on the basis of the expansion determinations.

The windowed cell was used to determine the compressibility of the separator gas at temperatures in the range minus 65 F to 100 F and at pressures up to 5000 psia. The data obtained are shown in Fig. 7. It was not possible to measure dew points of the separator gas at temperatures above 10 F.

Values of the function Pv/T illustrated in Fig. 7 and used in computing the specific volumes v and the compressibility factors Z are estimated to be subject to a precision uncertainty of 0.5 per cent. The computed values are recorded in Table 3.

● **Liquid-gas ratios of other mixtures of separator liquid and gas.** The measurements of liquid-gas ratios of the separator gas at temperatures in the range minus 65 F to 10 F are shown in Fig. 8. When it was discovered that the critical temperature of the gas was minus 45.2 F, or 18 F higher than the critical temperature of the mixture containing 72.47 mass per cent separator gas, other mixtures were prepared for critical state study. Mixtures containing 63.71, 68.09, and 84.04 mass per cent separator gas were tested in the windowed cell to obtain more information on the relation between the critical temperatures of the mixture and their compositions.

Specific-volume data obtained on the mixtures were limited as to temperature range and are not illustrated. However, values of the specific volumes v and the compressibility factors Z are given in Tables 4, 5, and 6 for the respective mixtures.

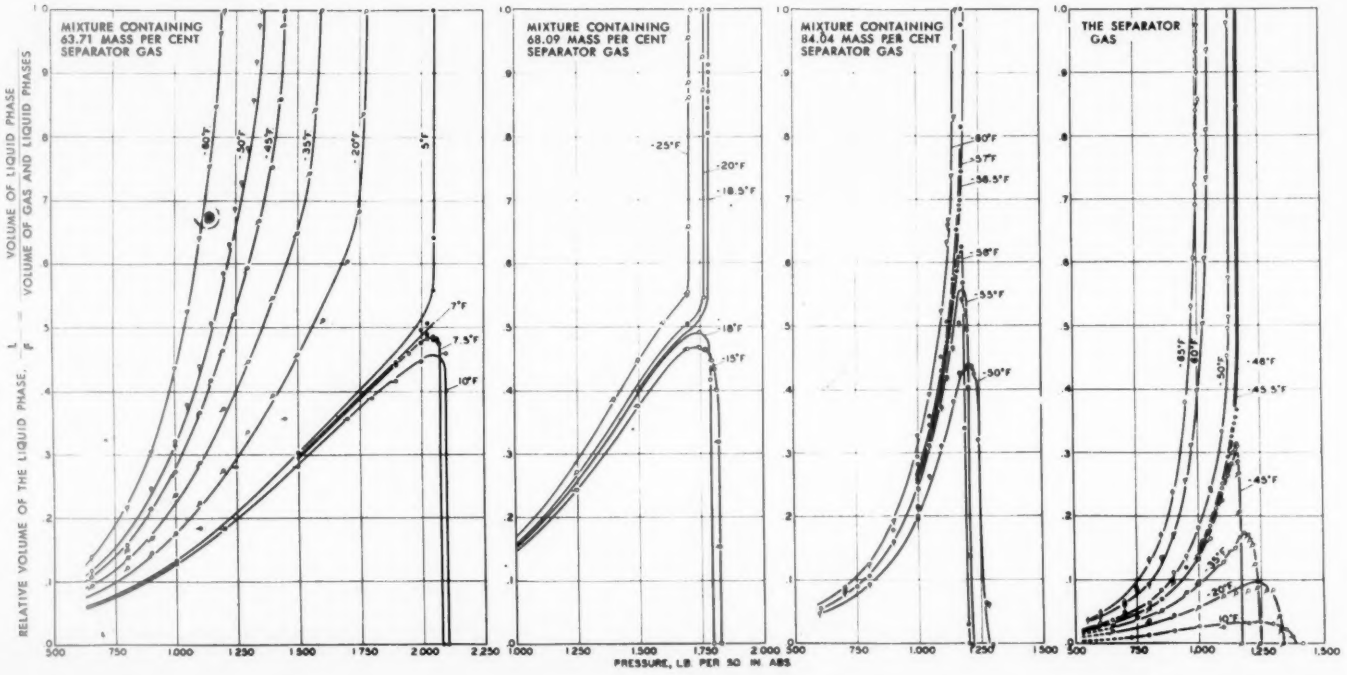
The curves of Fig. 8 for mixtures containing 63.71, 68.09, and 84.04 mass per cent separator gas are unlike those of Fig. 4 at pressures approaching dew-point pressures. The curves approach the pressure axis—zero value of liquid-gas ratio—almost perpendicularly. In working with the mixture containing 63.71 mass per cent separator gas at temperatures near the critical temperature, the liquid volumes increased gradually with increasing pressure until the critical pressure was closely approached and then either filled the cell or were totally evaporated with the application of only a little additional pressure. It was only by the most careful regulation of the pressure and temperature of the fluid that data could be taken at this stage of operation to show whether liquid-gas ratios increased or decreased just before the meniscus disappeared with an increase in pressure. Although this characteristic of the fluids aided in determining phase-boundary pressures for given operating temperatures, the precision uncertainty in determining the critical temperature of the mixture containing 63.71 mass per cent gas was increased.

The relation between the liquid and the total fluid volumes of the mixtures are shown on a relative volume basis in Fig. 9. The equations relating the specific volumes, the liquid-gas ratios, and the relative liquid volumes of the mixtures on which data are given in Figs. 7, 8, and 9 are reported in Tables 3, 4, 5 and 6 for the respective mixtures. The equations have the form of equation (2); only the value of the numerical constant is different. As previously discussed, the value of the numerical constant was determined by the mass per cent of gas used in preparing the mixtures.

● **Relation between composition of mixtures and their critical states.** The phase-boundary curves of all the mixtures of separator gas and liquid investigated are shown in section B of Fig. 10. The curve for the separator gas is extrapolated to the temperature and pressure at which the gas was in phase equilibrium with liquid in the field separator. The curves for the 68.09 and the 84.04 mass per cent gas mixtures cover only the narrow range of temperatures investigated. The critical states found for each of the mixtures are identified on their respective phase-boundary curves.

In section A of Fig. 10 the critical temperatures are plotted as a function of composition. The smooth curves connecting the data points indicate the critical temperatures that other mixtures of the separator gas and liquid would have. Critical pressures of other mixtures of these separator samples can be estimated by interpolating between the critical pressures indicated numerically at each datum point. If data on enough

FIG. 9. Relative volumes of the liquid phases of mixtures of separator liquid and gas combined in indicated mass per cent proportions.


MIXTURE CONTAINING 63.71 MASS PER CENT SEPARATOR GAS
MIXTURE CONTAINING 68.09 MASS PER CENT SEPARATOR GAS
MIXTURE CONTAINING 84.04 MASS PER CENT SEPARATOR GAS
THE SEPARATOR GAS
RELATIVE VOLUME OF THE LIQUID PHASE, L/F = VOLUME OF LIQUID PHASE / VOLUME OF GAS AND LIQUID PHASES
PRESSURE, LB PER SQ IN ABS

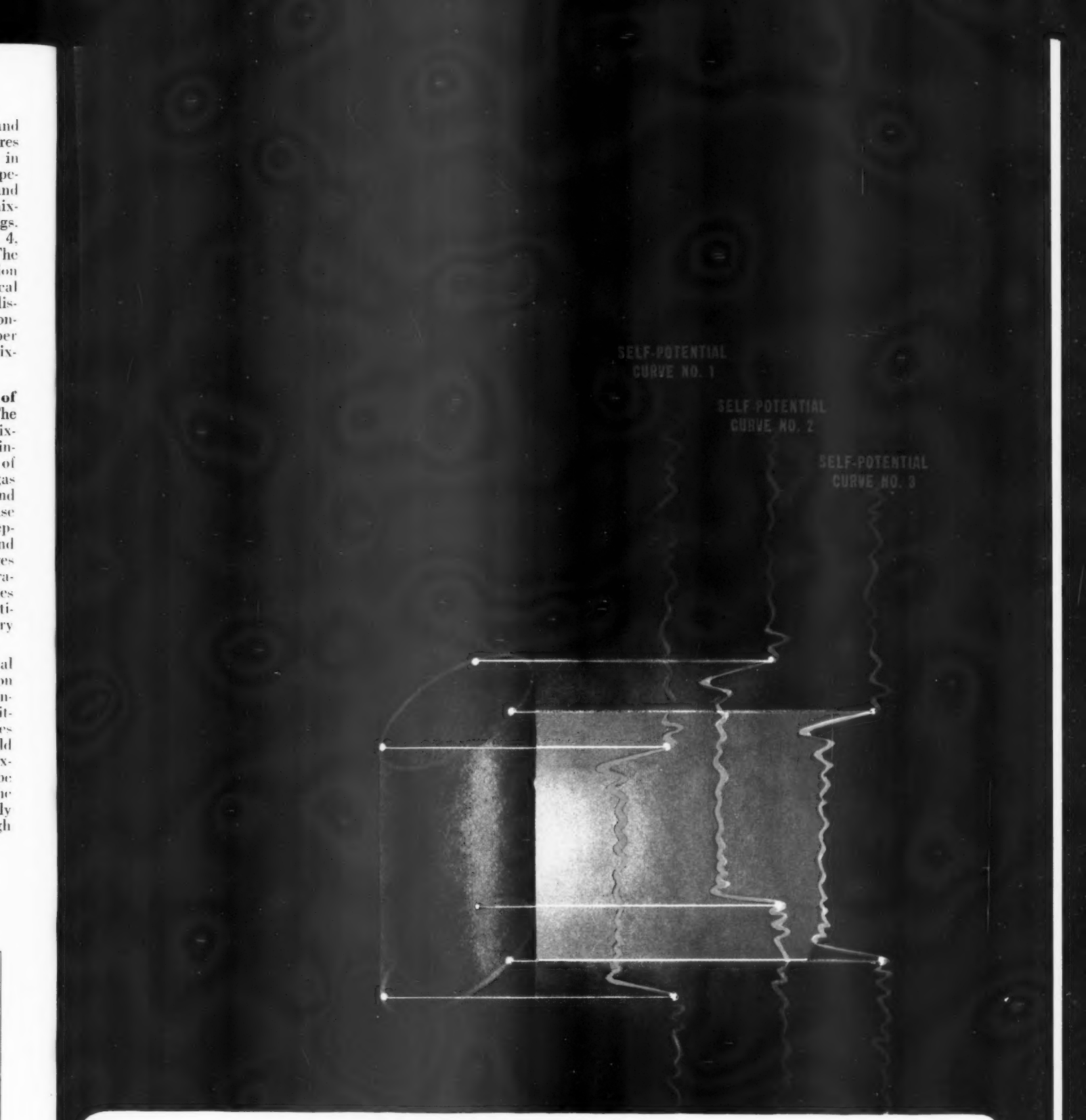


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TABLE 6. Properties of the mixture containing 63.71 mass per cent separator gas.

Pressure, psia	−60 F				−50 F				−35 F				−20 F			
	v	Z	L/F	l:g	v	Z	L/F	l:g	v	Z	L/F	l:g	v	Z	L/F	l:g
2000	..	..	1.000,0	..	..	..	1.000,0	..	..	..	1.000,0	..	..	..	1.000,0	..
1900	..	..	1.000,0	..	..	..	1.000,0	..	..	..	1.000,0	..	..	..	1.000,0	..
1800	..	..	1.000,0	..	..	..	1.000,0	..	..	..	1.000,0	..	..	..	1.000,0	..
1700	..	..	1.000,0	..	..	..	1.000,0	..	..	..	1.000,0	..	0.041,48	0.419,8	0.624,0	15.82
1600	..	..	1.000,0	..	..	..	1.000,0	..	0.038,90	0.383,7	1.000,0	..	0.044,54	0.424,2	0.537,0	14.62
1500	..	..	1.000,0	..	..	..	1.000,0	..	0.041,27	0.381,6	0.656,1	16.55	0.048,82	0.436,0	0.458,1	13.67
1400	..	..	1.000,0	..	..	..	1.000,0	..	0.045,31	0.391,0	0.545,9	15.12	0.054,16	0.451,5	0.387,2	12.82
1300	..	..	1.000,0	..	0.039,13	0.325,0	0.763,0	18.25	0.051,08	0.409,3	0.446,5	13.94	0.060,66	0.469,5	0.324,4	12.03
1200	0.036,96	0.290,5	1.000,0	..	0.045,06	0.345,5	0.575,1	15.84	0.058,52	0.432,9	0.360,1	12.88	0.068,83	0.491,8	0.267,9	11.27
1100	0.043,23	0.311,4	0.637,7	16.85	0.054,10	0.380,3	0.427,3	14.13	0.068,16	0.462,2	0.285,6	11.90	0.078,85	0.516,4	0.218,5	10.53
1000	0.054,82	0.359,1	0.436,6	14.63	0.065,54	0.418,7	0.317,0	12.70	0.079,82	0.492,0	0.224,4	10.95	0.091,22	0.543,1	0.176,1	9.82
900	0.069,00	0.406,7	0.305,9	12.90	0.079,64	0.458,0	0.236,0	11.49	0.094,54	0.524,5	0.174,6	10.09	0.106,9	0.572,6	0.140,5	9.18
800	0.086,56	0.453,5	0.219,6	11.62	0.097,48	0.498,3	0.177,2	10.56	0.113,4	0.559,3	0.135,6	9.40	0.126,9	0.604,6	0.111,4	8.64
700	0.109,7	0.503,0	0.161,0	10.80	0.121,1	0.541,7	0.134,1	9.93	0.138,7	0.598,3	0.106,2	9.00	0.153,6	0.640,1	0.088,6	8.32
600	0.141,3	0.555,4	..	..	0.154,4	0.592,0	..	..	0.173,2	0.640,4	..	..	0.190,2	0.679,4	..	..
400	0.257,9	0.675,7	..	..	0.274,4	0.701,4	..	..	0.299,2	0.737,8	..	..	0.322,7	0.768,4	..	..
200	0.624,2	0.817,6	..	..	0.651,7	0.832,8	..	..	0.693,2	0.854,5	..	..	0.731,5	0.871,0	..	..
14.4	10.46	0.986,5	..	..	10.73	0.987,6	..	..	11.14	0.989,2	..	..	11.56	0.990,6	..	..
Phase boundary	(1,185)† 0.037,43	0.290,5	1.000,0	22.88	(1,360)† 0.037,59	0.326,6	1.000,0	23.01	(1,590)† 0.039,04	0.382,6	1.000,0	23.82	(1,778)† 0.040,23	0.425,8	1.000,0	24.62

Pressure, psia	10 F			
	v	Z	L/F	l:g
2000	0.044,80	0.499,3	0.451,0	12.35
1900	0.047,13	0.499,1	0.423,8	12.21
1800	0.049,99	0.501,4	0.393,0	12.01
1700	0.053,48	0.506,7	0.358,5	11.72
1600	0.057,70	0.514,5	0.322,4	11.37
1500	0.062,90	0.525,8	0.286,1	11.00
1400	0.069,03	0.538,6	0.250,5	10.57
1300	0.076,62	0.555,1	0.216,1	10.12
1200	0.085,70	0.573,1	0.184,4	9.66
1100	0.096,69	0.592,8	0.155,5	9.19
1000	0.110,22	0.614,2	0.128,8	8.68
900	0.127,52	0.639,6	0.105,8	8.22
800	0.150,27	0.670,0	0.085,2	7.83
700	0.180,12	0.702,7	0.068,8	7.57
600	0.220,6	0.737,5	..	..
400	0.365,1	0.813,9	..	..
200	0.807,5	0.900,0	..	..
14.4	12.37	0.992,8	..	..
Phase boundary	(2,098)‡ 0.042,95	0.502,2	0.000,0	0.00

( )†=Phase boundary pressure at bbuble point, psia.
( )‡=Phase boundary pressure at dew point, psia.

$$\frac{Pv}{ZT}=b=0.382,1$$

$$(L/F)=\frac{0.001,636\ (l:g)}{v}$$

Critical temperature=7 F.
Critical pressure=2068 psia.
Critical specific volume=0.042,64 cu ft per lb.

TABLE 7. Properties of mixtures of separator gas and liquid at the critical state.

Property	Values of properties at indicated compositions, mass per cent separator gas				
	63.71	68.09	72.47	84.04	100.00
tc, °F	7.0	−18.3	−63.2	−56.3	−45.2
Tc, °F. abs	466.6	441.3	396.4	403.3	414.4
Pc, psia	2068	1785	1156	1198	1170
vc, cu ft per lb	0.042,64	0.042,72	0.041,01	0.047,94	0.065,60
b*	0.382,1	0.401,0	0.419,8	0.468,5	0.533,7
Zc	0.494,6	0.430,9	0.284,9	0.303,9	0.347,0
M, lb per mole	27.19	26.09	25.03	22.76	20.18
Correlating functions					
Mb	10.39	10.46	10.51	10.66	10.77
Mvc	1.159	1.115	1.026	1.091	1.324
PcVc/Tc	0.189,0	0.172,8	0.119,6	0.142,4	0.185,2
PcMvc/Tc	5.139	4.508	2.994	3.241	3.737
RTc/PcMvc†	2.088	2.381	3.585	3.311	2.872
bTc/PcVc=1/Zc	2.022	2.321	3.510	3.290	2.882
MPc/Tc	120.51	105.53	72.99	67.61	56.98
Pseudo-critical temperatures and pressures					
tc, °F	−20.0	−28.4	−35.2	−53.9	−73.6
Pc, psia	662	652	654	662	670

*Psia × cu ft per lb. / °F abs.

$$\dagger R=\frac{10.732\ \text{psia} \times \text{cu ft per lb mole}}{\text{°F abs.}}$$

mixtures were available over wide ranges of temperature, contours of pressure (isobars) could be drawn on Fig. 10 much as they were drawn in a previous study[9] (Fig. 16) of the bubble points of gas-condensate mixtures. The contours of pressure would indicate the phase-boundary surface and show dew-point and bubble-point pressures as a function of temperature and composition.

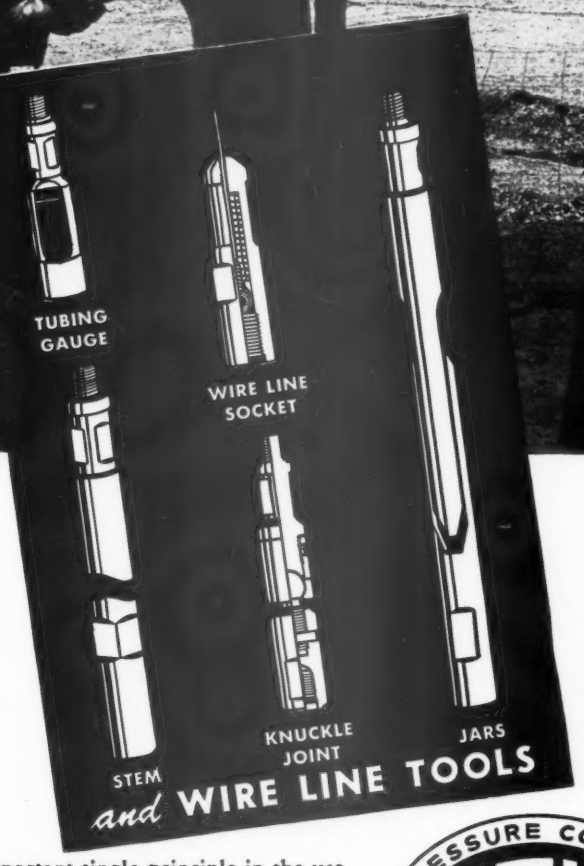
That the separator gas would have a critical temperature higher than that of the mixture containing 72.47 mass per cent separator gas was unexpected. If the influences of the critical temperatures of the components of a natural hydrocarbon mixture were additive, the separator gas with an average molecular weight of 20.18 would have a lower critical temperature than the flowing fluid with an average molecular weight of 25.03. The flowing fluid was a mixture containing, in addition to separator gas, 100.00 — 72.47 = 27.53 mass per cent of separator liquid of an average molecular weight of 68.64. The segment of the curve connecting the critical state data for the flowing fluid and the mixture containing 63.71 mass per cent gas indicates conformity to the additive law; the other segment reveals a different phenomenon.

In 1895, Kuenen[19], working with ethane and nitrous oxide and five mixtures of these gases, was the first to find that the critical temperatures of mixtures could be less than the critical temperatures of the pure component. By interpolation of the experimental results, it was found that a mixture containing 0.5 mole fraction ethane would have the lowest critical temperature. This minimum critical temperature was 78.4 F as compared to 89.6 F and 96.8 F, the values obtained by measurement of the critical temperatures of ethane and nitrous oxide, respectively. The values of the critical pressures of the mixtures were between the values of the critical pressures of the components. Mixtures of acetylene and ethane, and of carbon dioxide and ethane, later were studied by Kuenen[20], with similar results. A mathematical treatment involving the equation of van der Waals was used successfully in developing empirical equations for estimating the critical temperatures of each of the two-component mixtures studied.

Recently Rzasa[21] has investigated the critical states of mixtures of methane and a narrow-boiling-range mixture of heavy hydrocarbons known as Kensol 16, with results indicating that, for mixtures containing high weight per cents of methane, the critical temperatures are less than the critical temperature of methane (— 116.5 F).

There is some similarity between the composition-critical temperature curves shown in section A of Fig. 10 and the composition-temperature curves for the vapor and liquid phases of constant boiling mixtures. The flowing fluid (mixture containing 72.47 mass per cent separator gas) has the lowest critical temperature of any of the hydrocarbon

tops under pressure...



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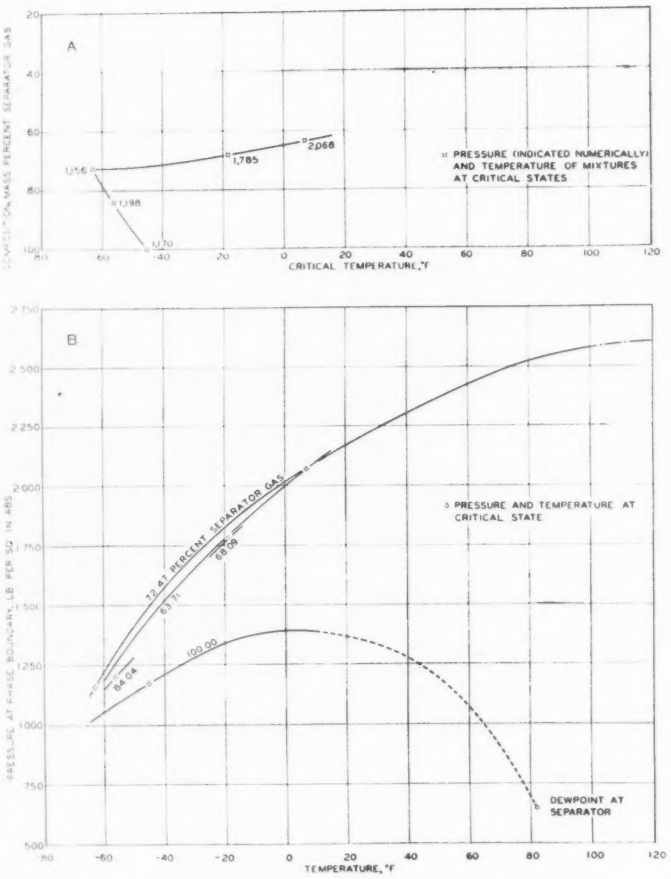

FIG. 10. Phase-boundary properties of the mixtures: A, critical temperature as a function of composition; B, phase-boundary pressures as a function of temperature.

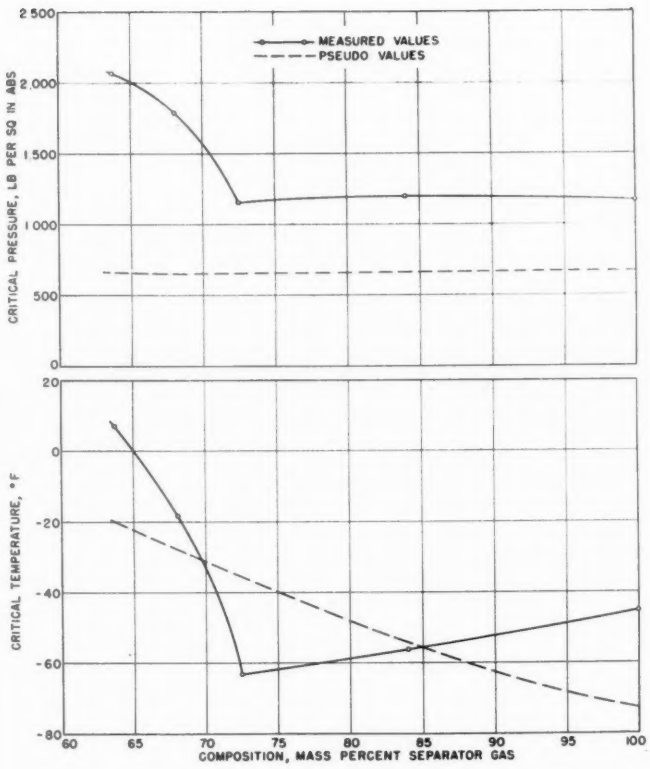

FIG. 11. Comparison of measured and pseudo values of critical pressures and temperatures of the mixtures.

mixtures and may be compared to an azeotropic mixture of minimum boiling point. However, the curves in section A represent temperature data on a single-phase fluid for a range of pressures; and the constituents used in preparing the mixture containing 72.47 mass per cent of separator gas both might have been of different composition, without affecting the composition of the flowing fluid, if they had been taken from the separator at some other operating temperature and pressure. The temperature and pressure of the reservoir from which the flowing fluid was obtained were 188 F and 2377 psia, respectively, and the production of a constant-boiling mixture is not implied.

The properties of the mixtures at the critical states are summarized in Table 7, where values of several functions in common use for correlating the properties of hydrocarbons also are given. The products Mb closely approach the value R = 10.732 of the universal gas constant expressed in engineering units. The volumes Mv_c of a mole of the respective fluids at the critical state vary with composition but the values lie on a smooth curve so that interpolation is not difficult. Values of the function $P_c v_c/T_c$ for 1 lb of fluid and the function $P_c Mv_c/T_c$ for 1 lb-mole of fluid can be related to composition by two smooth curve segments intersecting at the composition 72.47 mass per cent separator gas.

The dimensionless function $RT_c/P_c Mv_c$ was suggested by Cope, Lewis and Weber [1, p. 887] for comparing the properties of hydrocarbons containing more than three carbon atoms per molecule, and they proposed the value 3.78 as the mean value of the function for a number of paraffin hydrocarbons having molecular weights greater than 44. Although the gas-condensate mixtures studied had molecular weights in the range 20 to 27, the explanation for the low values of the function $RT_c/P_c Mv_c$ shown in Table 7 probably is embodied in the fact that the critical pressures of the mixtures are much higher than the critical pressures of the pure components.

The correlating function $bT_c/P_c v_c$ or $1/Z_c$ was obtained by substituting Mb for R in the function $RT_c/P_c Mv_c$. Except for the separator gas, values of the function were decreased slightly, and the difference between the greatest and the least values was increased by the substitution.

The correlating function MP_c/T_c also was suggested by Cope, Lewis and Weber [1, p. 887]. The proposed mean value of the function for hydrocarbons heavier than propane was 40.90 in the units designated in Table 7. The values of this function for the experimental data shown in Table 7 all exceed the value 40.90, with indications that the values of the function for gas-condensate mixture of molecular weight greater than that of propane could be higher still. The divergence is caused by the critical pressure term in the numerator of the function. As indicated in the introduction of this report, a correlating function is required for gas-condensate systems, which takes into account the fact that the critical pressures of the systems greatly exceeded those of the components. The divergences from average values of the correlating functions caused by the experimentally determined values of critical pressures of the systems indicate that the data being obtained may serve the purpose for which they are intended. Such possibilities of usefulness would be evident only after at least two studies like the present one have been completed.

The concept of the pseudo-critical pressure and temperature proposed by Kay[3] is useful in many applications of the theory of corresponding states to the solution of practical problems. Using data recommended in the Natural Gasoline Supply Men's Association Technical Manual [22, p. 48] and values of critical data computed by Wilson and

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Bahlke[23] for hydrocarbons heavier than the octanes, pseudo-critical values of temperature and pressure were computed for the mixtures the compositions of which are given in Table 1. The computed values are shown in Table 7.

Measured values and pseudo values of critical temperatures and pressures of the gas-condensate mixtures are compared graphically in Fig. 11. The curves of pseudo values are continuous, but the curves of measured values show discontinuity at the value of composition corresponding to the mixture representing the flowing fluid. Values of pseudo-critical temperature are appreciably affected by composition of the mixtures, which accounts, to some extent, for the success of the pseudo-critical concept in correlating compressibility factors of gases. Pseudo-critical pressures average less than half the values of measured critical pressures and composition has little effect on their values. In estimating such properties of gas-condensate fluids as dewpoint pressures and liquid-gas ratios, a correlating factor that will be sensitive to composition is needed. Measured critical pressures may be superior to pseudo-critical pressures for such purposes.

● **Summary.** By means of a windowed cell the specific volumes and liquid-gas ratios of a natural gas and four mixtures of condensate and the gas were determined at temperatures in the range —65 F to 100 F. The critical pressures and temperatures of each of the five mixtures were measured. Data for temperatures ranging from the critical temperature (—63.2 F) to the temperature of the cricondentherm (276 F) are presented on a mixture having the identical composition of the hydrocarbon fluid flowing from a gas-condensate well. Except for pressures less than 750 psi, substantially the entire two-phase region of the mixture was investigated experimentally. Pressures up to 5000 psi were used to obtain compressibility factors in the single-phase region and to determine the phase boundary of the mixture.

The information regarding the properties of the hydrocarbon mixtures at low temperatures was obtained to supplement and aid in correlating extensive data that have been obtained at flowing wells in the field by means of mobile equipment. Although useful correlations of hydrocarbon properties can be made on the basis of critical pressures and temperatures computed by additive methods, it is believed that such methods of correlation can be extended to new applications with increased accuracy by using actual values of the critical pressures and temperatures of mixtures. Measured values of the critical pressures of the mixtures investigated averaged more than 100 per cent higher than pressures computed by additive methods. Measured values of critical temperatures differed from computed values by extremes of 7 per cent on an absolute temperature basis.

An unexpected finding was that the critical temperature of the separator gas was higher than the critical temperature of the gas-condensate fluid flowing from the well. It is significant that experimental values of critical temperatures of mixtures particularly pertinent in production practice did not vary with the composition on an additive basis. For these mixtures, the critical temperature was found to be higher the more gas and the less condensate they contained.

The compressibility factors and the liquid-gas ratios of a gas were determined over a pressure and temperature range that included atmospheric conditions and conditions providing total liquefaction.

Data were obtained on gas-condensate mixtures by means of the windowed cell to add to the fund of basic information on natural hydrocarbon fluids at low temperatures. The low temperature data are expected to aid in the correlation of a quantity of data already available on the phase relations of fluids at the high temperatures and pressures significant in production and refining practice. The data obtained also have direct application in problems relating to the processing of gas-condensate fluids and the transmission of natural gas at low temperatures. The information on the liquid-gas ratios of the fluids in the region of the critical states can be a useful guide in the design of equipment for liquifying and storing natural gas at low temperatures.

● **Acknowledgments.** This is a report on a low temperature investigation conducted in cooperation with the American Gas Association for the purpose of providing fundamental information for correlating the properties of gas-condensate fluids significant in production, transmission, and storage practice. The assistance given by E. L. Rawlins, chairman of the Gas-Well Deliveries Subcommittee of the Natural Gas Department, American Gas Association, is gratefully acknowledged.

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The investigations are under the supervision of R. A. Cattell, Chief, Petroleum and Natural Gas Branch, Bureau of Mines, and H. C. Fowler, supervising engineer, and C. J. Wilhelm, engineer in charge of production, Petroleum Experiment Station, Bartlesville, Oklahoma. Thanks are due H. M. Huffman of the Bureau of Mines for comparing the Thermocouple used in the investigations with the accurate temperature standards available in his laboratory. H. C. Miller and N. A. C. Smith of the Bureau of Mines offered valuable suggestions helpful in the preparing of the report. Colleen Good assisted with the computations. Earlene Baldwin prepared the illustrations.

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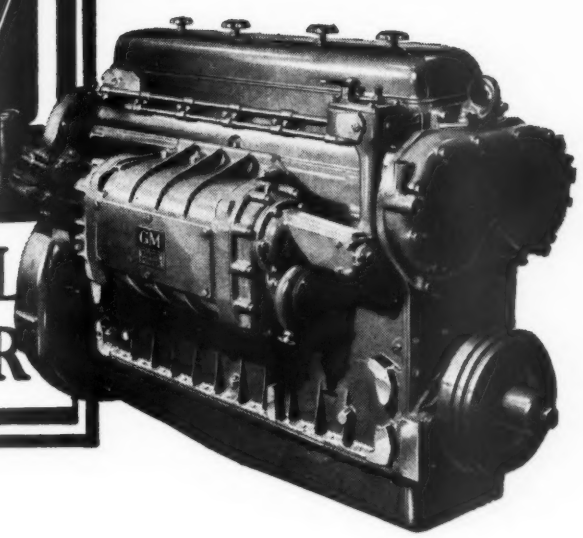

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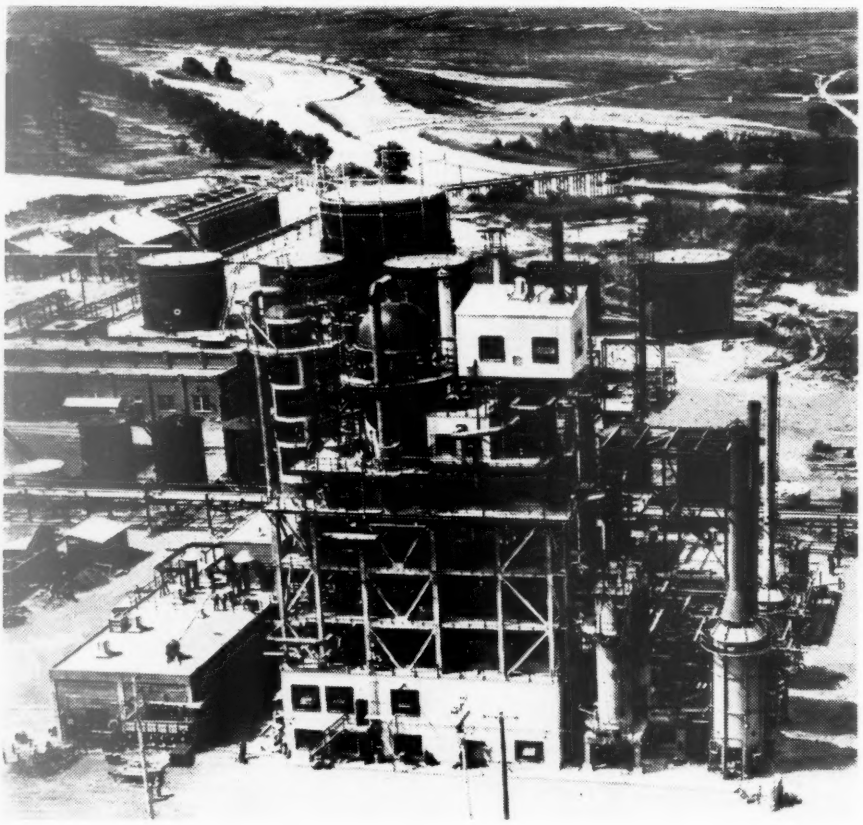


The new unit that was specifically designed to meet the needs of the small refinery. Overall height is reduced; reactor and regenerator are supported at the same levels; an outside spent catalyst is provided; the fractionator is in reality a tri-functional vessel with a rectifying section, a desuperheating section, and a slurry settler all combined into one compact tower; piping has been simplified; the electrical precipitator has been changed to a cylindrical shell for operation at a higher pressure than in former fluid units.

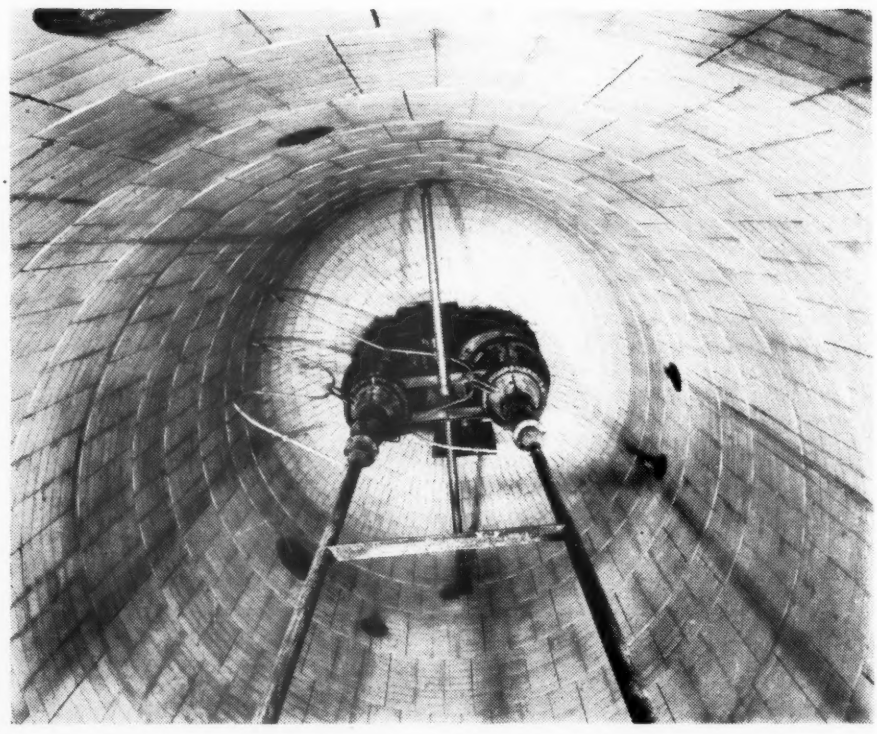
Below is the top of the regenerator of the plant. The two cyclone separators in parallel prevent small catalyst particles from escaping with the flue gases. Recovered catalyst is returned to the main regenerator bed via the dip pipes shown. All gases leaving the regenerator must first enter the throat of one of the cyclones. Once in, the gases (and any entrained catalyst) are forced to travel a circular path due to internal baffles. The catalyst particles, being heaviest, are thrown to the outside of the cyclone by centrifugal force, and pass down a collecting duct into the dip pipe, which returns recovered catalyst to the main bed of regenerator.

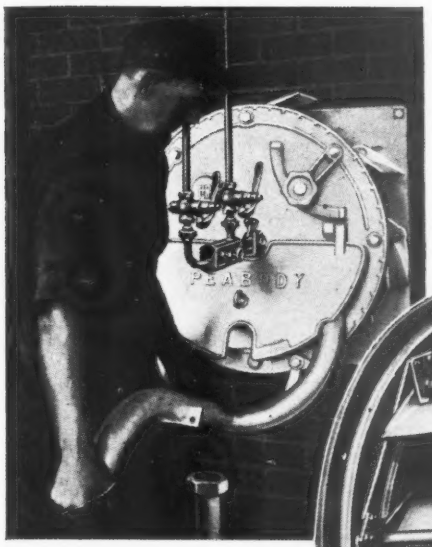
Casper unit model of small refinery design

THE first small fluid cat-cracker to be built since the end of the war went on stream last Fall at the Casper, Wyoming, refinery of The Texas Company. Rated at 4000 bbl a day capacity, the new unit is intended to serve as the focal point of an expansion and consolidation program of The Texas Company at Casper, which will make its Casper Works (10,000 bbl per day crude charge rate) a model of small refinery planning.

The cat-cracker was designed and constructed by The M. W. Kellogg Company, petroleum engineers of New York, who are also revamping and building catalytic polymerization, naphtha reforming, and pressure coking facilities in the same refinery.

A new "balanced pressure" design is embodied in the unit. As a result, reactor and regenerator are supported at the same levels, an overall reduction in height has been effected, and standpipe heights have been reduced. The reduced standpipe heights in turn enable a lower pressure drop to be maintained across the slide valves and so eliminate much of the erosion formerly found in these crit-





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HEAVY DUTY GAS AND OIL BURNER

Burns either fuel alone or both simultaneously

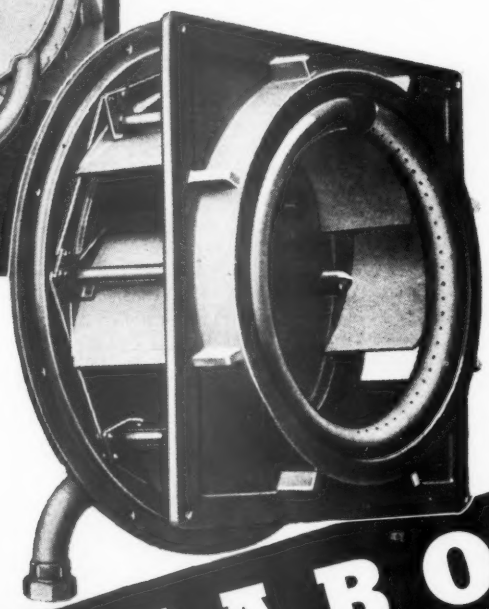
Gas enters the furnace throat from a ring that is quickly replaceable while oil is being burned, if the gas ports become clogged. Center fired gas burners are also available.

For firing with oil, all Peabody Oil Atomizers, steam or mechanical, may be used.

The air register is designed to provide adequate control over flame characteristics and furnace conditions, with either natural draft or forced draft.

Heavy construction withstands damage and assures long life.

Simplified design makes installation easy and provides a strong wall and burner assembly.



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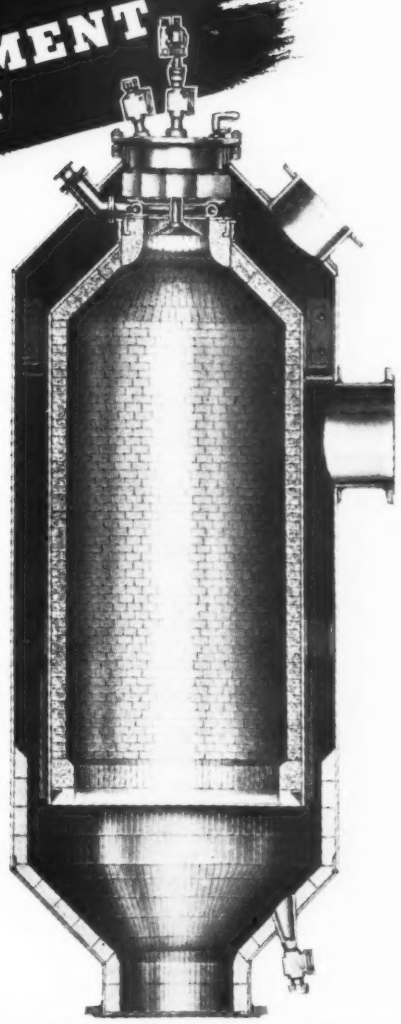

Direct Fired High Pressure Air Heaters

They are built for any working pressure and air delivery temperature.

The burner is a Peabody Combined Type, firing gas and oil. In the event of fuel failure, the burner can be quickly re-ignited while the furnace is under pressure.

Peabody Air Heaters are furnished as complete units, comprising the furnace, burner and all required controls. They are in service in synthetic rubber and high octane gasoline plants, also with gas turbines to reheat waste gases.

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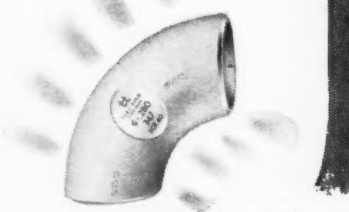

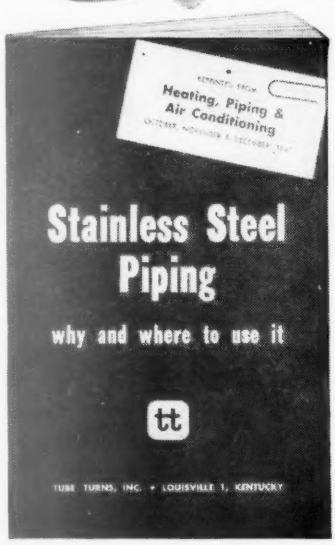

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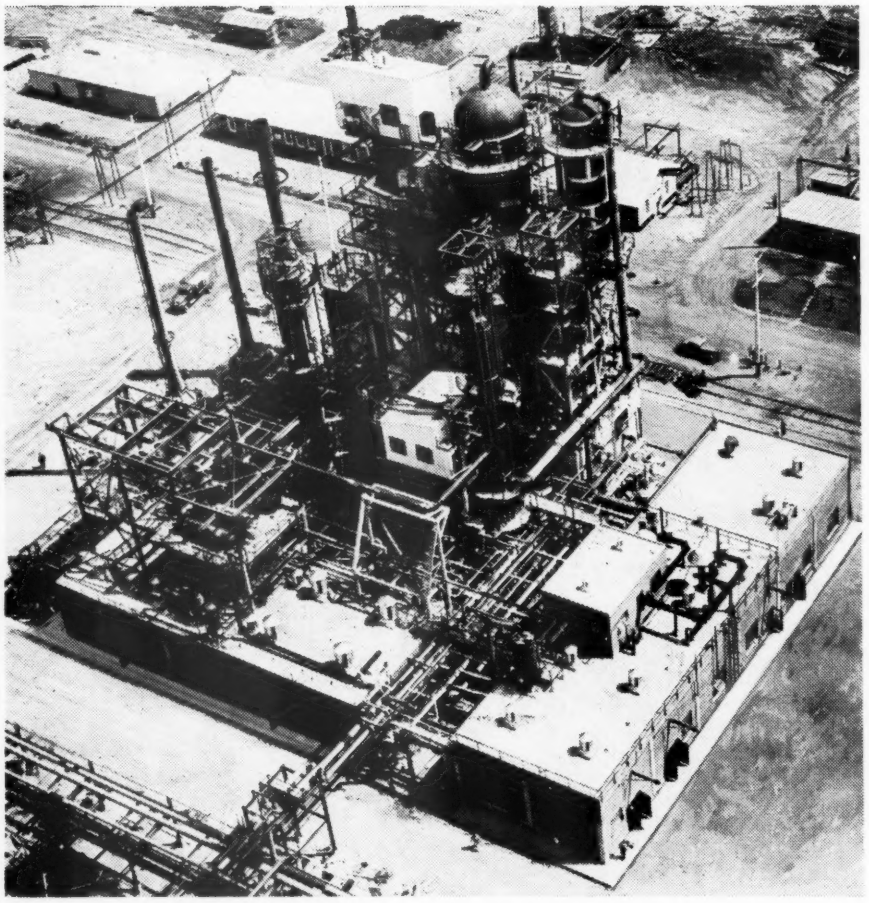

This oil refining unit embodies a new design with a number of improvements made to lower initial investment and operating cost on refineries with a crude oil processing capacity of about 10,000 bbl per day.

ical catalyst controlling mechanisms. Piping, too, has been simplified, with short direct runs to all major vessels and with only one expansion joint in the whole unit.

The plot plan, arranged in the shape of an elongated oblong, brings the reactor, regenerator, and precipitator into line in a main structure at the extremity of the battery limits. At the opposite face of the oblong, a second row of vessels brings the fractionator and gas recovery equipment into line. This oblong arrangement, *open on all four sides with all big vessels on the outside*, enabled each vessel to be lifted into position as soon as it arrived on the job site without interfering with other erection proceeding simultaneously. The installation of piping, structural steel, and internal auxiliary vessels was not delayed by this outside arrangement of the big vessels, nor did each large vessel in position interfere with the installation of its neighbor. As a result, the unit is a model of construction efficiency and clearly shows the effect of plot plan and vessel arrangement on construction costs, construction time, and ease of maintenance.

Some highlights of the new design are:

(1) A new cylindrical electrical precipitator designed to operate at high pressure replaces the former box type. Additionally, it saves one-third of the investment cost through greater ease of fabrication on a leak-free basis and by reduction of reinforcing required.

(2) Consolidation of the fractionator into a tri-functional vessel with a rectifying section, de-superheater, and slurry settler all included in one tower has also reduced initial costs and improved the safety of the unit by eliminating danger of flash.

(3) An outside stripper, separate from the reactor, efficiently disengages oil from catalyst and returns the oil vapors to the top of the reactor. Preventing oil from entering the regenerator with the spent catalyst reduces the size of the regenerator and the air blowing equipment required.

(4) All major vessels, except the regenerator, were shop fabricated with generous alloy provision for corrosion due to the high sulphur content of the gas oil processed.

(5) All pumps, compressors, and blowers are steam driven for reliability and ease of control. The unit itself generates most of the steam required for this purpose by recovery of heat from the flue gases and from the hot slurry that has been circulated to de-superheat the reactor vapor. ★★★

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NEW EQUIPMENT

(1) International TD-24

The International TD-24 crawler tractor is now in production, according to an announcement of International Harvester's Industrial Power Division.

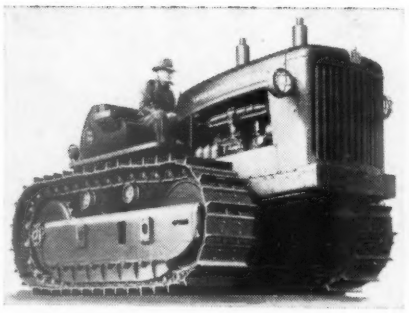
As an indication of the tractor's power, the following figures are provided:

Power at flywheel	180
Horsepower at driving end of belt from power take-off	167
Horsepower at drawbar	140

The TD-24 weighs 36,275 lb not including fuel, water, attachments, or dunnage. Additional weight, with fuel tank and radiator filled but without attachments, brings the total to 37,178 lb.

The tractor is entirely new, including its 6-clyinder, 4-cycle, 180-hp diesel engine. It is built for high-speed operation as well as tremendous pull. It is said to be as easy to control as a modern automobile despite its great size and horsepower.

A complete line of matched tractor equipment is available for the TD-24. These include angle-blade dozers, bulldozers, land clearing blades, power control units, pusherplates, scrapers, rippers, logging winches and arches, canopies, oil field winches and pipe booms. All have been designed and engineered for the TD-24 through close alliance between the International engineering department and the engineering departments of the allied tractor equipment manufacturers.



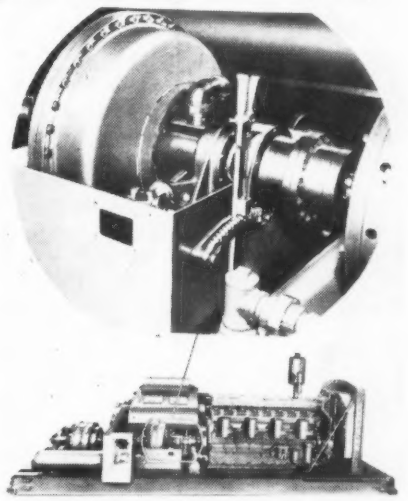
(2) Fluid-drive rig

A built-in fluid-drive is the outstanding feature of new Ideal Sectional Drive Groups for Ideal Type 100 and Type 125 Consolidated drilling rigs manufactured by The National Supply Company. This development, with its greater compactness and increased flexibility of operation, follows 12 years' experience with separate hydraulic couplings. The drive, in the 600-hp size, adds only 37 in. to the length of the conventional engine assembly.

The Ideal-Gyrol Fluid-Drive, as the new development is known, was designed to cushion the flow of power between the engine and the rig, and to give a highly flexible control of speed and power over a wide range of operating conditions. As in similar motor car fluid drives, power is transmitted without mechanical connection from the engine to the driveshaft by means of a cushion of oil between two vaned rotors. This cushion absorbs harmful torsional vibrations and reduces shock loading of pumps, hoisting equipment, and the drilling string.

A distinctive feature of the Ideal-Gyrol Fluid-Drive is its rapid regulation of the volume of oil in the rotors by means of a sliding scoop. This scoop may be used to maintain various degrees of filling and to alter the driving characteristics of the coupling. The coupling can also be quickly emptied of oil by means of the scoop, thus completely disengaging the engine from the power take-off shaft. This eliminates the conventional friction clutch power take-off on the engine. The scoop is normally operated by a hand lever on the drive but may also be arranged for operation at the driller's position by an air cylinder.

It is possible to operate either the drawworks or rotary table with the couplings partially filled, thus operating with a soft drive at slow speeds when such characteristics are desired.

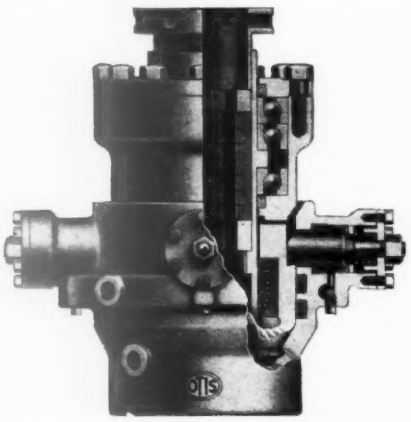


As a slush pump drive, the fluid-drive smooths the flow of power at the high efficiency of 96 to 98 per cent in normal pump operation. Under special conditions pump speed can be decreased to a complete stall at full discharge pressure while the engine continues to operate in an efficient range. Fluid drives are available for independent pump assemblies as well as on the Sectional Drive Group. The Ideal-Gyrol Fluid-Drive is also a valuable adjunct to the compounding of power pumps.

(3) Drilling head

Otis Pressure Control, Inc., announces the manufacturer of the new Type D Otis drilling head and pressure operated union, adaptable to high pressure drilling operations especially in the field of reverse circulation.

Designed to operate safely up to 1500 psi mud pressure, the hook-up can be used in reverse circulation or conventional drilling, for drilling in or cleaning out under pressure, for blowout prevention, and for carrying excess pressure on the mud column. It is operated by a remote control pressure manifold placed at a convenient spot on the derrick floor, thus eliminating the necessity of men working under the floor during drilling operations.



The drilling head permits rapid coupling and uncoupling, maintains a constant seal around a square or hex kelly, and remains on the kelly during the entire drilling operation.

(4) Variable speed changers

Wide application of Link-Belt P.I.V. Gear variable speed changers throughout the industries has required constant enlargement of the available capacities of this unique, all-metal, positive, infinitely variable speed unit.

Continuing in this process of expansion, Link-Belt Company now announces having installed and being in production on a Size H-6 unit, which extends the line through 25 hp.

The H-6 unit is rated 20 hp for speed variation ratios of 5 to 1 and 6 to 1, and 25 hp for speed change ratios of 2 to 1, 3 to 1, and 4 to 1.

It is made only in a plain, basic Type No. 1 horizontal assembly, with housing split horizontally. In other words, the housing consists of a top and bottom half, instead of the central housing and side plate construction employed on the smaller P.I.V. Gear sizes.

With the addition of the H-6 unit, the Link-Belt line of P.I.V. Gear variable speed changers now embraces eight sizes.

The new, H-6 size of Link-Belt P.I.V. Gear variable speed changer.

(5) Electric generators

In The Buda Company's new line of industrial gasoline engine electric generator sets there are 23 models available in d-c or a-c output, single or three phase, in sizes from 10 kw to 125 kw. Each set is complete and fully equipped with controls, generator, radiator, and engine all mounted on a self-contained base.

The gasoline engine (also available with natural gas and butane engines) is water cooled and compactly built. Full circulating pressure system of lubrication is provided to all crankshaft bearings, camshaft bearings, rocker arm bearings, and rocker arm shaft. Equipment on engines includes electric starter, lubricating filter, and air cleaner.

The generator is direct connected, single ball bearing heavy duty, drip-proof construction, and conforms to AIEE and AEME standard. Control panel is complete with voltmeter, ammeter, circuit breaker, rheostat, and engine controls.

Gasoline generator sets are designed for both standby and standard service. When designed for standby service, the engine speed is moved up so that greater kilowatt capacity may be obtained on the same set. When used for continuous or standard service the engine speed is set so it will have a long continuous life.

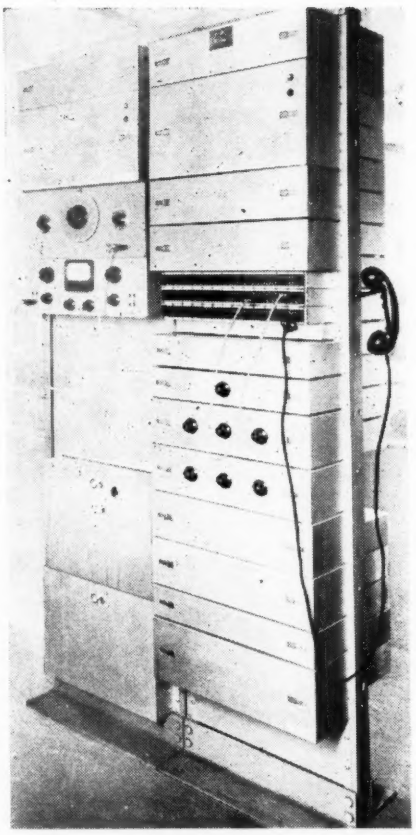
(6) 11-Channel carrier

Lenkurt Electric Company, prominently identified with the manufacture of wire-line carrier-telephone systems, introduces a new system designed to provide as many as 11 duplex voice channels on a two-way radio circuit. Referred to as Type 42, the equipment was developed to answer the need for multichannel radiotelephone link installations such as those between islands in Pacific areas where cables are economically impracticable, according to the manufacturer; however, the equipment offers similar advantages on radio circuits of a wide variety of types.

The carrier equipment is shown in the right hand rack in the illustration, while the rack to the left contains measuring and telegraph gear.

On installation, carrier equipment is required only at the terminals of the radio link—intermediate repeater stations involving radio-frequency relaying only. Carrier channels can, however, be terminated or connected to side circuits at any repeater point with appropriate equipment.

Of special interest is the design feature that permits a 15-kc program channel with one to eight added carrier channels. This provides order wire circuits, channels for facsimile, circuits for telegraph, or telemetering or remote control over studio-transmitter links.



A complete line of f-m and a-m telegraph equipment, signaling apparatus for ringdown or toll dialing, and control and telemetering gear is available for use with this carrier equipment. Power-supply voltage and frequency requirements are matched to the particular installation.

(7) Fluid-sealed stuffingbox

The Vernon Tool Company, Ltd., announces its new Vernon "Fluid-Sealed" stuffingbox, that is said to have the following features:

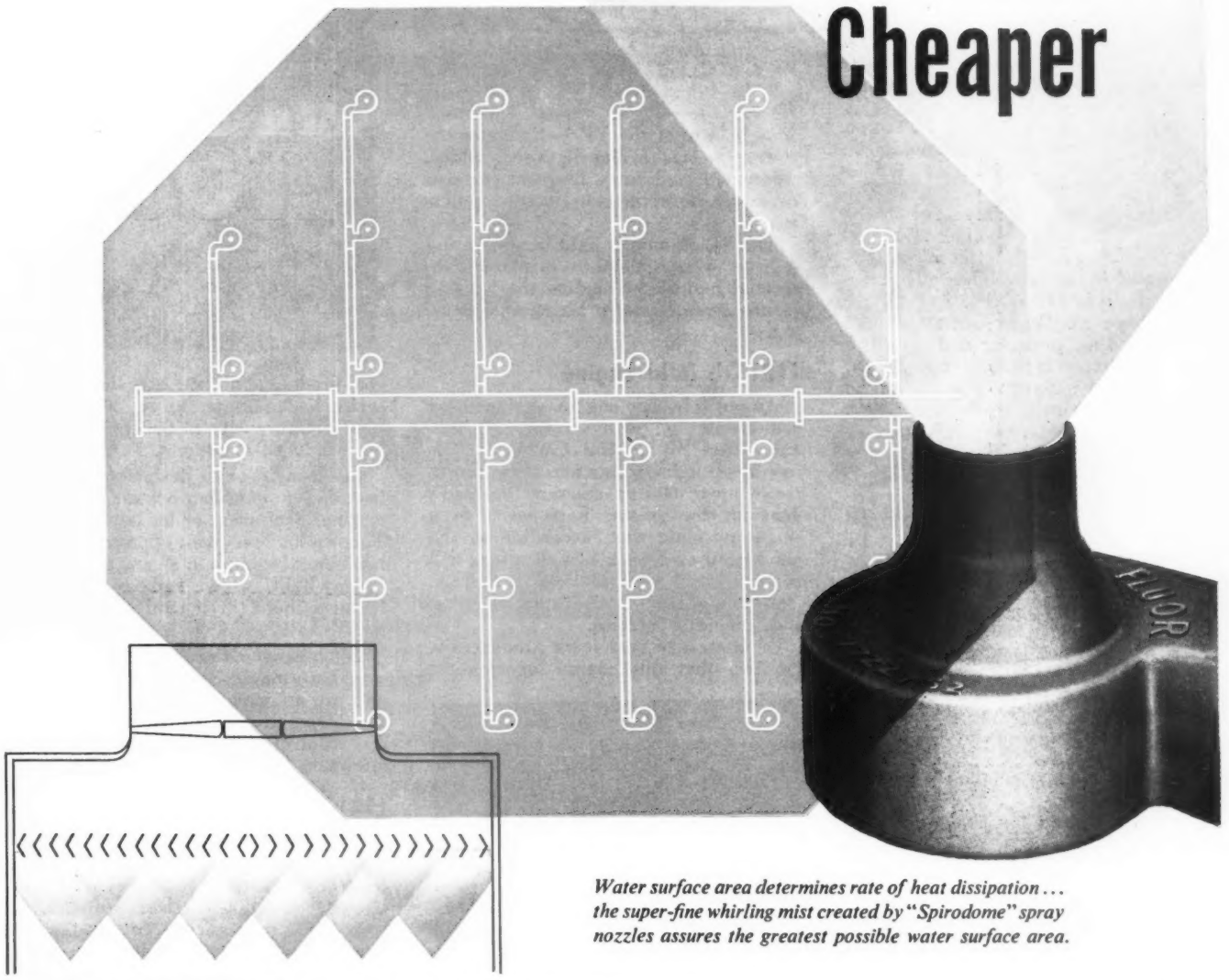
1. The only metal parts that may contact the polish rod are made of brass, which eliminates the danger of scoring the rod and indefinitely prolongs the life of the packing element.

2. A long-lasting, one-piece, oil-resistant packing element. Should it be necessary to replace, the process is rapid, inexpensive, and requires no tools.

3. Packs off firmly around rod through action of fluid pressure within a specially moulded packing element. Torque-free bearing raced cap must only be taken up hand tight for effective pack off.

4. Heavy walled steel body has standard 8V thread to fit conventional wellhead.

THOROUGH AIR-WATER MIXTURE = Colder Water Cheaper



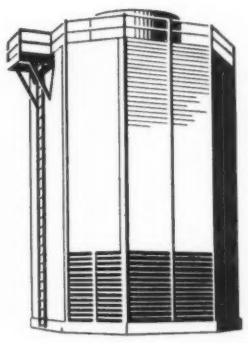
Water surface area determines rate of heat dissipation... the super-fine whirling mist created by "Spirodome" spray nozzles assures the greatest possible water surface area.

Cheaper? Yes, and here's why: The upspray distributing system in the Fluor "Counterflo" induced draft cooling tower, which incorporates the patented "Spirodome" Spray Nozzles, adds 8 or 9 feet of *unseen* cooling tower height. Here's how:

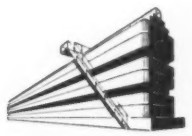
Water is sprayed 6 to 8 feet up into a spray chamber, where the drops are broken up into minute particles, and where the great heat load is flashed off before the drops even reach the first deck. Therefore the function of the decking is not to release the great bulk of the heat, but rather to cool the water to as close to wet bulb temperature as possible.

This system is a "must" where hot water is to be cooled, since the upper portion of the tower is at least twice as effective as the same tower with the usual flume and splash plate system.

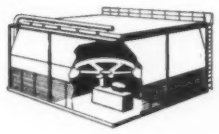
Yes...Fifty years' experience proves Fluor Cooling Towers will, year in and year out, deliver colder water cheaper.



Fluor "Counterflo" induced draft cooling towers, prefabricated in mass production, are available in multiple or single units in any required size or height.



Fluor areator atmospheric cooling towers are recommended where conditions make this type most practical.



The Fluor Fin-Fan cooling unit has a wide, economical range of utility throughout industry.

FLUOR

BE SURE WITH FLUOR

PRODUCTS : *Cooling Equipment, Mufflers, Gas Cleaners, Pulsation Dampeners*

SERVICES : *Designers and Constructors of Refinery, Chemical and Natural Gas Processing Units*

THE FLUOR CORPORATION, LTD., *Los Angeles 22* · NEW YORK · PITTSBURGH · KANSAS CITY · HOUSTON · TULSA · BOSTON

(8) Casing protector

Patterson-Ballagh announces a new casing protector. This new style protector is streamlined to insure the best protection for both casing and drill pipe. The rubber lips that have proved so successful in the older style protectors, are incorporated in the smooth contour of this new style, it is announced. The streamlined shape minimizes turbulent mud flow around the protector and permits a minimum change in the direction of mud flow. Formerly, abrupt changes in the direction of the mud around the casing protector produced a scouring action directly above and below the rubber and "ringing" of the drill pipe occurred.

Streamlined casing protectors are manufactured from the same special PBX D 25 rubber that has proved itself in deep well drilling, it is pointed out. They will keep their shape in any type of mud or brine and always grip the pipe firmly. Long contact surface that takes the wear instead of the casing or tool joint and the rugged lip construction gives gripping power at each end of the protector.

This new casing protector is now available in most of the popular sizes and will soon be available in all sizes.

(9) Sump pump

Designed to overcome one of the most common causes of pump failure—breaking of the pump shaft seal because of water pressure—a new sump pump, known as the VP-4 has been announced by the Gardner-Denver Company.

The design of the VP-4 embodies a new principle—"top suction." Because of this feature, the oil seal of the VP-4 is subjected only to static pressure from depth of immersion when the pump is not in operation. When the pump operates, water cannot reach the oil seal on air motor.

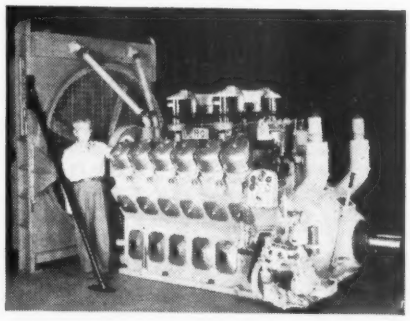
The VP-4 sump pump is operated by a powerful vane-type air motor. The pump impeller of the closed type is made of exceptionally hard, abrasion resistant alloy. A built-in oiler lubricates all moving parts of the pump with oil, the oil chamber having one-quart capacity for 24 hr normal operation. This feature of the VP-4 eliminates the grease fittings ordinarily used, which, when neglected, are a frequent cause of bearing failure, the manufacturer points out.

The VP-4 pump is light in weight and easy to move from place to place. Substantial handles welded to the housing assure greater ease in lifting and carrying.

(10) Oil field engine

An entirely new engine, designed for heavy duty, oil field service has been announced by Le Roi Company. The new V-12 engine with a maximum power range up to 600 hp answers the field's demands for greater horsepower in a single portable unit, according to the manufacturer. Possible applications will be found in heavy rotary drilling rigs, mud pump drives, pipe line pumping and generator service.

Of interest to petroleum producers is the fact that this engine incorporates

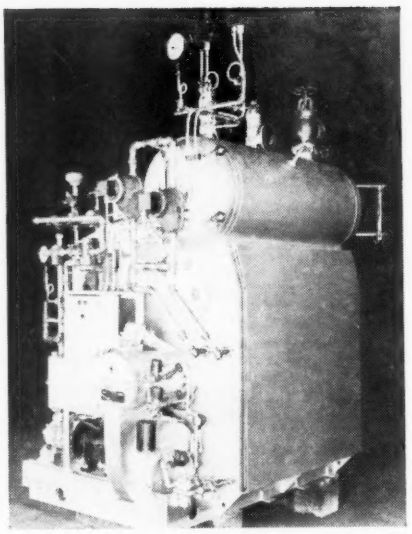


many new features designed for continuous service. A V-12 cylinder engine, with a 7¼-in. bore and 7-in. stroke, the displacement is 3467.7 cu in. Weight as illustrated is 13,500 lb. The engine design, under development for more than four years, includes overload valves, individual cylinder heads, removable cylinder sleeves, one-piece crankcase, hydraulic valve operating mechanism, water-cooled manifolds, modern cam-ground pistons with full-floating pins and full pressure lubrication. The fuel system is adaptable to natural gas, liquid butane, and gasoline.

(11) Package steam generator

Foster Wheeler Corporation announces its entry into the field of package steam generators up to and including 27,000 lb per hr range. These Foster Wheeler units are assembled at the factory, including refractory and insulation, and are ready to generate steam when delivered and installed.

Designs immediately available provide for both oil and gas-firing, and a



coal-fired unit will be ready shortly. Two series, low pressure (up to 250 psi), and high pressure (up to 850 psi), are being produced at present.

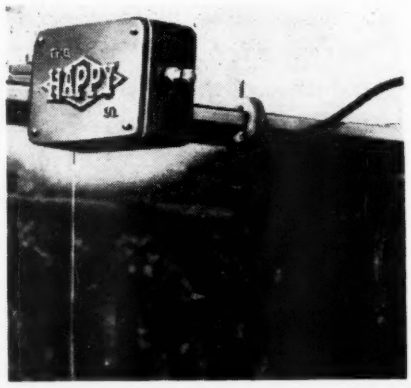
Basic engineering design provides for installation of super-heaters either as original equipment or for later addition. This means that plant operators are being offered complete steam generators, factory-built, which embody the same features found in central station units, it is asserted.

Combustion controls provide full or semi-automatic operation, as desired, and are an integral part of the "package." Operation of the units from a central control panel is simple—only a minimum of attention is necessary.

(12) Pump protector

A new type of pumping unit protection known as "The Happy Beam Safety Switch," has been introduced by the Happy Company. An inertia switch, it trips on shock loads to short out the engine magneto or to shut down the electric motor to prevent pumping unit damage caused by excessive loads. The device is a 24-hr watchdog to keep lifting costs at a minimum by eliminating repair costs and excessive shut-down time.

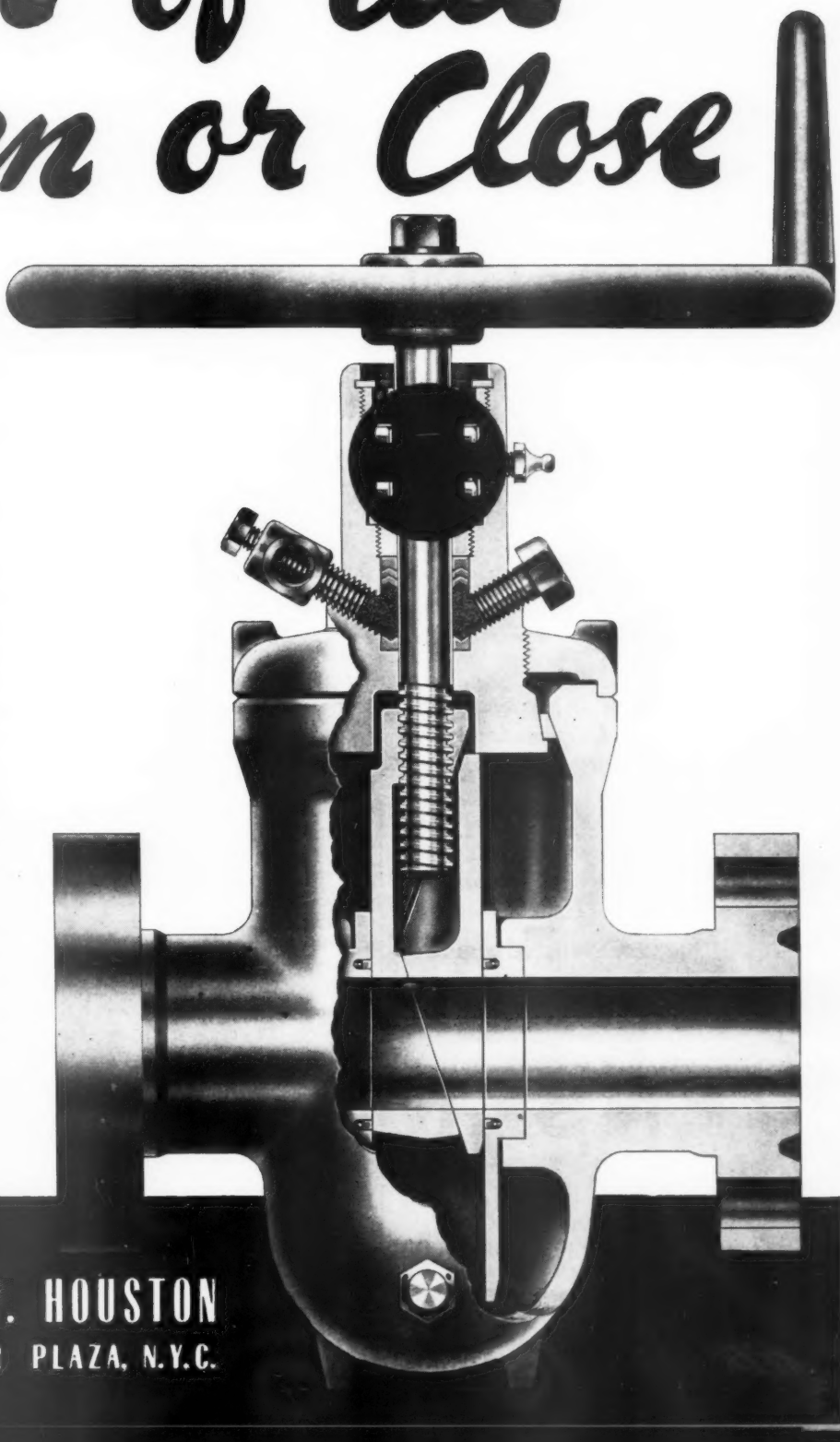
The design has many unusual features: (1) Reset from ground; (2) wide range of adjustment; (3) completely enclosed; (4) high quality, oil-proof wire; (5) easily adjustable, and (6) quickly installed.



Now DOUBLE ROLLER THRUST BEARINGS ON STEM MAKE W-K-M GATE VALVES

Easiest of All to Open or Close

All possible chance for binding and freezing has been eliminated in this new W-K-M Through-Conduit Gate Valve design that includes double roller thrust bearings on the stem. It will open easier than any other valve . . . easier than any previous W-K-M Valve . . . under full rated pressure. In addition, you'll find other features about this new W-K-M Valve which are simply refinements of a design that has proved itself through years of service under all conditions. Check these features against any other valve: Through-conduit opening with no turbulence or restriction of flow . . . Parallel expanding gates which seal directly across both seats with no distortion whatever to give positive shut-off on both sides . . . Lubricant contained in entire body —no special lubricant required and seal does not depend on lubricant. Ask your W-K-M Representative about the other exclusive features.



W-K-M COMPANY, INC. HOUSTON

EXPORT: 30 ROCKEFELLER PLAZA, N.Y.C.

(13) Short haul carrier

The Federal Telephone and Radio Corporation, affiliate of International Telephone and Telegraph Corporation, has answered the needs of many organizations requiring wire transmission facilities over moderate length lines by the development of a small-size three-channel short-haul carrier system, known as the FTR 9-H-1, which will operate on open telephone wire for distances from 100-150 electrical miles.

The value of such a short-haul system as the 9-H-1, which costs only $660 per terminal, can easily be appreciated when a customer estimates that it would cost about $200 per mile to install a new transmission line on existing poles.

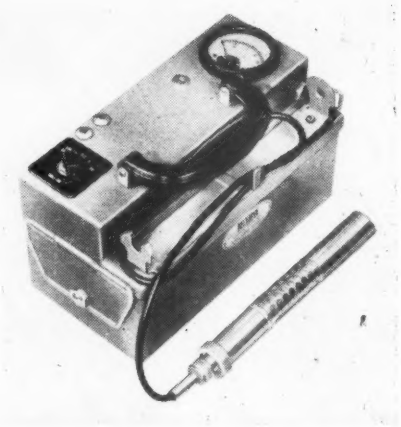
The 9-H-1 carrier system has many unusual features. It occupies only 7 in. of vertical rack space per channel and weighs only 35 lb. The transformers, coils, filters, and capacitors are hermetically sealed and mounted on rear of panels, the company reports.

Another new development is the FTR 9-F-1 second-story single-channel carrier system, which provides an additional channel for operation on the same pair of wires with an FTR 9-A-1 single-channel carrier system.

(14) Radiation meter

The growth of atomic energy projects and the expanding use of radioactive substances have developed a need for better instruments to detect and measure radioactivity. Protection of personnel and the safe handling, not only of radioactive substances themselves but also of materials, such as photographic film, which can be damaged by exposure to radiation, are serious problems that are encountered in many industrial and research operations.

Recognizing this need, National Technical Laboratories, manufacturers of Beckman pH Meters and other Beckman instruments, has developed several portable radiation instruments incorporating many novel design features. Recently announced is the Beckman Model MX-5 Radiation Meter, a portable Geiger-Muller counter weighing only 9 lb, for the detection and measurement of X, beta, and gamma radiations. It is ideal for the measurement of radioactivity of low intensity, such as locating isolated radioactivity leaks or lost radioactive materials in factories and industrial applications, for mineralological surveys, for checking apparatus and equipment for contamination by small amounts of radioactive materials, for following the course of tracer elements and other radioactive materials of low intensity, and for laboratory and experimental work.



(15) Tube cleaner

To meet the demand for an efficient, light-weight, easy-to-operate condenser and heat exchanger tube cleaner, The Airetool Manufacturing Company is now producing a new geared cleaner powerful enough to cut through the heaviest scale, and yet a cleaner that is extremely light-weight—the motor weighs only 35 lb. This unit will clean any type of scale in tubes 3/8 in. to 1¾ in. ID and will thoroughly clean tubes that are completely closed with scale, the manufacturer states.

The outer case of this Model CC-375 geared cleaner is of sturdy, light-weight aluminum alloy. All moving parts are made from alloy steel heat treated for uniform grain and hardness. It is powered by an air or steam driven motor that has a maximum of 1200 rpm. A conveniently placed handle valve affords the operator constant, positive control. The flushing agent is introduced through the motor and the driveshaft to the cutting edges to flush out removed deposits and to insure a cool drill. The packing glands of this cleaner prevent leakage of the flushing agent. A variety of drills and cutting edges may be used with this cleaner.

(16) Service parts kit

A new and complete line of 31 Service Parts Kits, designed for use in overhauls of Cummins diesel engines, has been introduced by Cummins Engine Company, Inc. The entire line of kits is described in detail and illustrated in a 36-page parts kit catalog

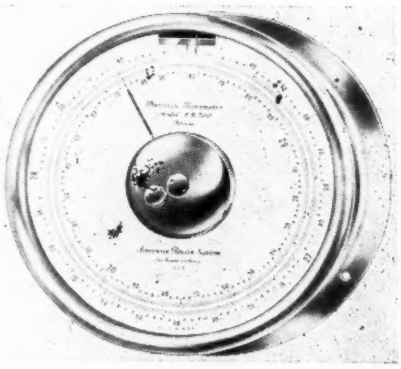
Each of the 31 kits in the new series contains all the genuine Cummins parts needed to overhaul a specific sub-assembly unit of the Cummins diesel engine.

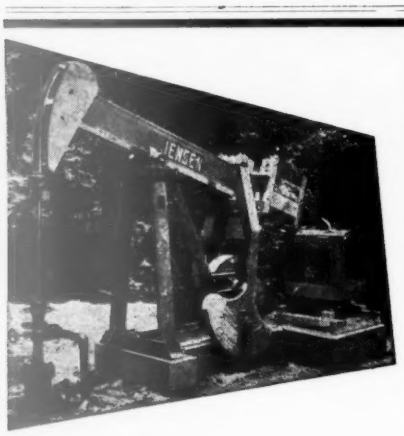
Conveniently-packaged and easily-stored, the kits will help engine owners complete their overhauls easier and faster and provide important savings on each overhaul, according to the Cummins Parts Merchandising Department. Kit prices, it was pointed out, are considerably less than the cost of the parts purchased individually.

(17) Precision barometers

A new series of Precision Barometers is now being manufactured by the American Paulin System. The outstanding instrument in the series is the PB500, for the first time, an aneroid instrument that is graduated in intervals of 1/500 in. of mercury.

American Paulin System's exclusive system of instrumentation eliminates all friction-creating mechanisms, according to the manufacturer. The slightest change in atmospheric pressure is instantly indicated on the dial and read directly in inches of mercury.





JENSENS
do it best

All pumping units will lift oil. Some do it better than others—and producers who've been buying Jensens for 28 years say Jensens do it best.

This just didn't happen. Our experience and engineering knowledge have proved that one-step gear reduction, roller bearings, electric welding, plus the manufacturing know-how makes Jensens more dependable and economical to operate.

If you're one satisfied with nothing but the best—see your Jensen dealer or write us.

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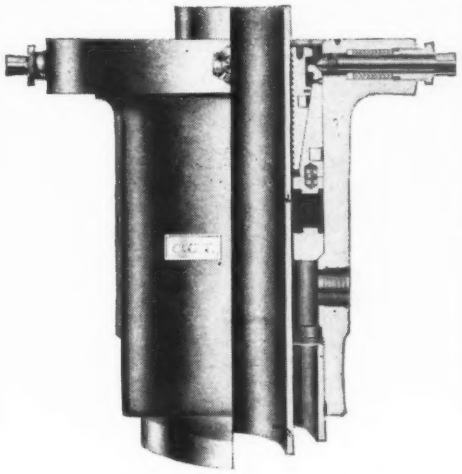
(18) O-C-T casinghead

Oil Center Tool Company has announced a new deep well casinghead for safely suspending and sealing extremely long and heavy casing loads. The manufacturer asserts that the new wellhead enables the operator to suspend and seal his pipe with blowout preventers installed above the well bore, utilizing slip suspension and the weight of the casing to compress resilient packing to effect a seal.

Specifically, the manufacturer points out the following features of the Type "C-19" casinghead:

Slips, packing element, and bowl are a single split unit that is wrapped around casing, latched and dropped into the head with elevators holding desired tension on the casing.

Upon reaching its seat in the casinghead body, suspension at the desired



tension and a seal are automatically effected as weight of the casing string applies sealing compression to the Hycar seal rings.

The hanger assembly may be lowered through blowout preventers, thus providing suspension and seal with the blowout preventers in place.

The Hycar seal is under constant compression without displacement, and is confined on all sides by steel, protecting the seal rings against deterioration. Additional compression may be applied to the seal by means of lock-down screws provided in the casinghead flange.

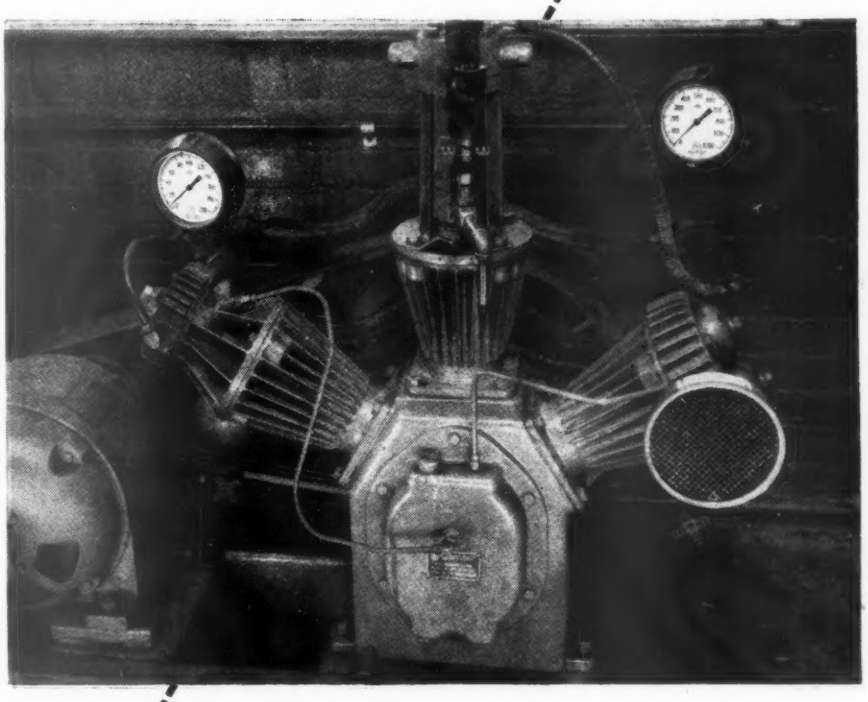
(19) Protective coating

Duratex, which is currently used by several large utility and oil companies, is now available to general industry, it has been announced by National Petroleum Sales, Inc.

This new pipe protective coating has exceptional resistance to electrolysis and corrosion, the destructive electrochemical reaction that costs the utility, oil, water, and electrical industries millions of dollars annually for repairs and replacement, according to the manufacturer.

Damage to the pipe coating compound due to shock impact caused by falling stones, etc., when the line is backfilled is one of the hazards reduced by Duratex. which has outstanding shock impact resistance, it is stated.

Here's how HELICOID GAGES

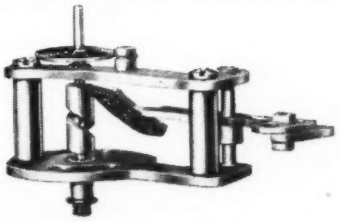


PAY OFF!

On a compressor like this, where you have vibration and rapid pressure pulsations, ordinary gages with clock gear movements last but a short time. Sometimes the gears are worn out in a few weeks.

By comparison, Helicoid gages wear for years. Actually, the gages shown here have been in service for 2½ years and are still going strong.

This is an example of the saving in maintenance which can be made by using Helicoid—the gage of enduring accuracy.



Only Helicoid Gages have the Helicoid Movements

ACCO

TRADE MARK

HELICOID GAGE DIVISION
AMERICAN CHAIN & CABLE
Bridgeport 2, Connecticut

trade literature

PUBLICATIONS LISTED ARE SENT FREE UPON REQUEST

(20) Mechanical rigs

Oil Well Supply Company has issued a new 16-page booklet No. 1C-1047, entitled "Oilwell" Mechanical Rigs, descriptive of the "Oilwell" No. 96 drawworks, the No. 1000 dual and triple-engine drives, the No. 64-B drawworks, the No. 500 dual engine drive, and the "Oilwell" Brantly hydraulic feed control. The booklet is of interest as it describes many design features of the "Oilwell" machinery not yet generally known to the industry.

(21) Transco V-belt drives

Transmission Machinery Corporation has released a 16-page catalog on Transco V-belt drives, with combination groove sheaves for "A" or 'B" section V-belts. Necessary data are given so that standard drives can be selected using stock sizes of sheaves and V-belts.

(22) Neoprene notebook

The *Neoprene Notebook* is published approximately four times a year by the Rubber Chemicals Division of E. I. du Pont de Nemours and Company. The publications contain information on laboratory results and industrial applications for neoprene products. Through the course of a year, *Neoprene Notebook* contains articles dealing with many branches of industry.

(23) Barco joints

Barco Manufacturing Company has issued two bulletins, one on its swivel joints, the other describing its flexible ball joints. Barco swivel joints are for use on air, oil, gas, steam, water, and other fluid lines and, according to the manufacturer, will not leak under alternating steam and cold water. They provide a 360-deg swivel movement with side flex to take care of piping alignment.

Barco flexible ball joints are for service with lines handling oil, steam, air, gasoline, gases, etc., where a flexible conveyor is required. They provide a 360-deg swivel movement plus 40-deg total angular movement and are suitable for all pressures up to and including 300 psi steam working pressure, in standard types and sizes.

(24) Heat transfer apparatus

A new bulletin on finned-tube heat transfer apparatus has been published by The Griscom-Russell Company. An introduction to the bulletin describes the purposes of fin-type elements and the services to which they are adapted. The applications of elements with helical F-Fins and with longitudinal G-Fins are fully explained. The various designs of condensers, heaters, coolers, and heat exchangers supplied with each of these finned elements are concisely described, with explanations of their advantages in the services for which they are intended. The bulletin is profusely illustrated with exterior and interior views of the units and cross-sectional drawings showing their construction.

(25) Stopping cellar wall leaks

A new leaflet describes the advantages of Smooth-On No. 7 Iron Cement, widely used to seal leaks in concrete, brick, or stone walls and floors. The leaflet explains how Smooth-On No. 7 may be applied effectively to inside as well as outside surfaces, and used on either wet or dry surfaces. It also illustrates other uses for this composition, including surfacing and dust-proofing new concrete floors, and lining cisterns, pools, tanks, fountains, etc., repointing joints between brick, concrete, or stone blocks, and sealing openings around piping extending through walls or floors.

(26) Fuel oil burning system

Schutte and Koerting Company announce a new three-color 8-page bulletin on mechanical fuel oil burners used for operating steam boilers in industrial and power plants. Photographs, text, and drawings describe the burners, together with general information on their construction and operation.

Tables, drawings, and charts give comprehensive data on dimensions, pressure capacities, and weights of the various burners, forced and natural draft air cooled registers. Pumping systems for fuel oil burners also are described. Photographs show typical applications of the burners in hotels, industrial plants, and a large utility.

(27) Wire rope manufacture

A new booklet "Life-Line," shows the various processes of manufacturing wire rope from wire rods through wire and rope mills. The story is presented in pictures with short captions in a similar manner to a strip film. Booklet size is 4½ in. by 5 in. and contains 56 pages.

The manufacturer, Macwhyte Company, states that this booklet, No 48-1, is obtainable on request.

(28) Allis-Chalmers oil equipment

Allis-Chalmers equipment for the oil industry, built in a maximum range of types and sizes, is described in a new 20-page bulletin released by the company. Products covered include Texrope power transmission equipment, drilling rigs, electric motors, motor controls, transformers, unit substations, generators, shale shakers, blowers, compressors, and centrifugal pumps.

Described and portrayed are the three types of power units for oil drilling rigs built by Allis-Chalmers. These are Texrope driven mechanical rigs, electric-mechanical and d-c full-electric rigs. Also featured is the company's new line of totally enclosed fan-cooled motors in sizes up to 2000 hp engineered to meet the particular needs of pipe line companies and oil refineries .

Allis-Chalmers employs specialized engineers who check every oil industry installation carefully, the bulletin points out.

(29) Onan standby folder

"Keep going—with Onan standby power," is the theme of a new 17 by 20, 2-color broadside entitled, "Onan Standby Everywhere," recently issued by D. W. Onan and Sons, Inc. This interesting folder describes how standby electric power provides protection from electric powerline breakdowns by the installation of Onan emergency electric plants.

A table of capacities of Onan emergency plants is included along with a description of the Onan automatic a-c line transfer controls, which are designed to switch over the electrical load to the standby unit within seconds after mainline power fails.

(30) Grip elevator and spider

Bulletin No. 347, 12 pages, describes and fully illustrates the mechanical features of National Supply Company's Ideal automatic grip elevators and spiders, in four sizes to handle casing ranging from 4¾ in. OD to 13⅜ OD and any length strings. The bulletin covers all details of design that contribute to long trouble-free service, includes lubrication procedure, specifications of four standard sizes, and dimensional diagrams.

(31) Alco products and service

Alco Products Division of the American Locomotive Company has issued a bulletin concerning its products and services. Equipment and industrial installations featured in the booklet are: (1) Pressure vessels and fabricated plate work, (2) heat exchange equipment—bare or fin tube, (3) prefabricated piping, and (4) diesel engines. Under the Alco plan, whereby all four groups of equipment are produced by a single organization, a saving in design and production time is effected, it is stated. Such a plan permits the shipping of units in proper sequence, and the meeting of "close" installation schedules.

Alco also is making a featured business of complete overhaul and repair service on heat exchangers through its subsidiary company, Beaumont Iron Works.

UNEQUALED

—AS A PRESSURE REDUCING REGULATOR
—AS A BACK PRESSURE VALVE

THE

NIXON

"Selective Flow Differential"

HIGH PRESSURE

REGULATOR

•

← *Nixon Regulator reducing 2000 lbs. to 500 lbs.*

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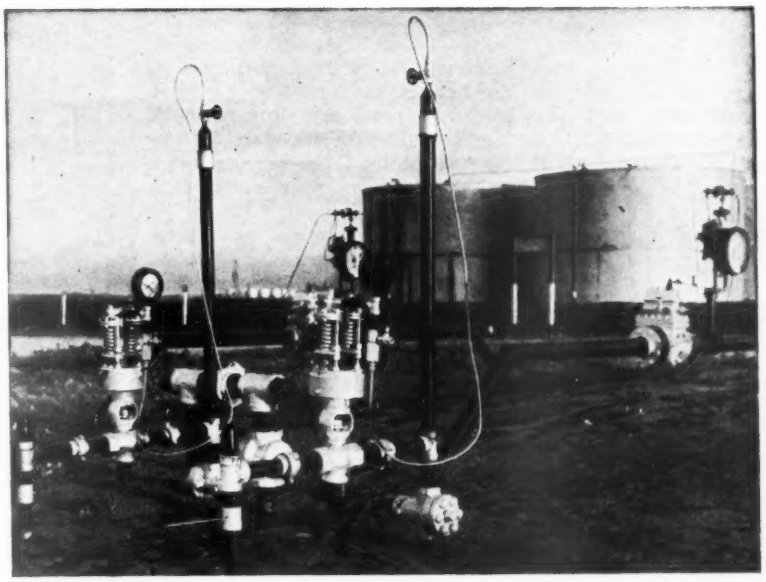
↓ *Back Pressure Regulators on Vent lines from high pressure separators.*

The Nixon High Pressure Regulator has proven to be the "most versatile" of all Regulators.

Field men throughout the Industry have found this Regulator adaptable to almost any job where pressure control is desired.

Yes — for Pressure Reducing, for Back Pressure work, as automatic Stop Cocks on Christmas trees of flowing wells, and for Well Purging . . . you can depend on the Nixon Regulator for outstanding performance.



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SALES OFFICES: Tulsa, Oklahoma; Dallas and San Antonio, Texas.
LOS ANGELES: Western Pressure Control, 5700 Santa Fe Avenue.
TRINIDAD, B.W.I.: Neal Massey Eng. Corp.

BRANCH STORES: TEXAS—Kilgore, Beaumont, Barbers Hill, Bay City, Monahans, Alice, Victoria, Corpus Christi, Columbus. LOUISIANA—Lake Charles, New Iberia, Harvey, Shreveport. ARKANSAS—Magnolia. MISSISSIPPI—Natchez.

(32) Twin-line liquid pumps

The Cooper-Bessemer Corporation has issued a bulletin on its 'Twin-Line' high pressure liquid pumps, which, the manufacturer states, represents a new development in design and construction compared with conventional duplex and triplex types. The "Twin-Line" pumps are applicable to a number of services where liquid is pumped against high pressures, such as: Oil pipe lines; pressure maintenance by water injection in oil production, and for water flooding; lean oil pumping in absorption plants; hot and cold oil charging service in oil refining; de-scaling service in steel mills; de-barking logs in the wood pulp industry; high-pressure boiler feeding, and many other uses.

(33) Tank car cleaning

Owners and handlers of tank car fleets will be interested in reading an article describing a special unit that provides rapid, thorough, automatic cleaning of tank car interiors. The article is featured in the November-December issue of *Oakite News Service*, house publication of Oakite Products, Inc.

The article describes how this unit, known as the Oakite Interior Tank Cleaning Unit, Model 324, provides four outstanding desirables in connection with tank car cleaning: (1) Rapid action; (2) thorough cleaning; (3) safety of operation; and (4) lower cleaning cost per car. Used in conjunction with a recommended detergent, the unit makes possible automatic cleaning of three to four cars per day, it is asserted.

(34) Piston ring catalog

The C. Lee Cook Manufacturing Company, announces the publication of a new 36-page catalog No. 470 fully describing the complete line of Cook Graphitic Iron Piston Rings for industrial size diesels and compressors.

The catalog gives details on ring design and construction, ring service, and ring specifications. Included are engineering tables, diagrams, and data, as well as practical suggestions relative to the ordering of piston rings.

(35) Rotojet tube cleaners

The complete new line of Rotojet tube cleaners manufactured by the Elliott Company, Roto Division, is described and illustrated in a new bulletin. The company asserts that the power, efficiency, and cleaning speed of its new Rotojet tube cleaners greatly exceed any produced during its 38 years of specialization in the manufacture and sale of tube cleaners. Also shown in the new bulletin are various types and sizes of Rotojet motors for operation with water, compressed air, and steam. Parts and accessories illustrated, include various types of heads, air valves for one-man operation, lubricators, and hose. Tables list sizes and type of tubes, and specify the Rotojet tube cleaner recommended for each.

(36) Booklet on diesel operation

Lanova Corporation announces the publication of a new 58-page handbook-size booklet entitled, "The Lanova Combustion System for Diesels." This booklet gives an up-to-date description of the Lanova Combustion System, what it is, and how it functions. Throughout the text, stress is placed on the importance of proper combustion in economical diesel operation.

Included is such elementary material as is considered necessary to give the reader a clear understanding of the subject. Points that are discussed are comparisons between types of fuels, differences between internal and external combustion engines, and gasoline and diesel engines, as well as a full description of how a diesel operates.

In presenting the subject of combustion the booklet illustrates and discusses representative types of diesel combustion systems. Engineering tables and data are also included.

(37) Aldrich triplex pump

New Data Sheet No. 66 completely pictures and describes the Aldrich inverted vertical triplex pump for petroleum, central hydraulic, and high pressure applications. It contains standard ratings, approximate dimensions, and diagrams of comparative discharge flows; describes the construction and operation of the pump; points out its low maintenance features. An isometric drawing and various charts are used to illustrate outstanding design features.

(38) Electrode wall chart

A 25-in. by 35-in. electrode wall chart, beautifully printed in full color, has been published by The Hobart Brothers Company. This handy wall chart shows procedures for every type of arc welding electrode; actual results of too long or too short an arc, too much or too little welding heat, too fast or too slow a welding speed, and then shows a perfect bead as well as a cross-section of all welds; and complete illustrated welding symbols for both fusion and resistance welding.

Bulletin 476, "Stainless Steel Dimensional Data," by Taylor Forge and Pipe Works describes welding fittings from ¾ in. to 12 in., and lightweight American Standard flanges from ¾ in. to 30 in., all available in stainless types 304, 316 and 347, monel, inconel, nickel, copper, and other usual industrial metals.

(39) Westinghouse Axiflo fans

An 8-page color booklet describing the economic and versatile performance of the new line of Westinghouse Axiflo fans suitable for high temperature applications has been released by the Westinghouse Electric Corporation. Especially significant in the design is the low resistance cone housing that keeps the motor, belts, and all bearings out of the air stream, thereby introducing a great variety of high-temperature applications never before possible with conventional fans, according to Westinghouse officials.

(40) Regulators, strainers, traps

The O. C. Keckley Company is offering a special bulletin featuring precision pressure regulators, temperature regulators, and combination pressure and temperature regulators, self-cleaning strainers, and steam traps. It includes dimensions, application, capacity, and engineering tables and specifications. Engineers are invited to write for this bulletin.

(41) Wire rope connectors

Presenting its complete line of Electroline-Fiege wire rope connectors, the Electroline Company announces a new 32-page catalog. Generously illustrated with cut-away views to show how cable and strands are positively anchored, the catalog includes a condensed analysis of the three main types of connection—open end or clevis type, eye end type, and stud end type; with all dimensional specifications and simple illustrated intruction material covering installation. The catalog is of handy pocket size and is printed in two colors.

(42) Otis controls and equipment

Otis Pressure Control, Inc., has published a 32-page, two-color, catalog containing nearly 50 illustrations and drawings, and complete operating details, data, and dimensions of all Otis sub-surface controls, equipment, and special services. Covered in the catalog are several new types of tools and equipment including the Otis surface safety valve, two-zone pumps, pressure-lock packers, completion tools, and snubbing and control equipment featuring new type control heads.

(43) Gas measurement services

John P. Squier, Gas Measurement and Engineering Service, has released a 4-page, two-color, illustrated bulletin describing an orifice meter chart integrating and computing service; a field and shop meter reconditioning and repair service; a new automatic bearing shaft lubricator, and the availability of several other special gas measurement services.

(44) Valve capacity calculator

A valve capacity calculator, offered without charge and applicable to the new K&M line of Kontrol-Motor diaphragm valves and pressure regulators, is available from Kieley and Mueller, Inc. The calculator was developed from the results of extensive laboratory tests and is based on three factors: (a) Rate of flow through the valve, or capacity; (b) static pressure and pressure drop, or resistance; (c) valve size.

(45) Welding fittings and flanges

The Tube-Turn Catalog and Engineering Data Book No. 111, which is recognized as an authority on the subject of welding fittings and flanges for industrial piping, now has a 20-page supplement. The supplement is devoted to specifications that cover new items in the expanding line of Tube-Turn fittings. It is 6 in. by 9 in. and slips easily into the pocket provided for it on the inside back cover of No. 111.

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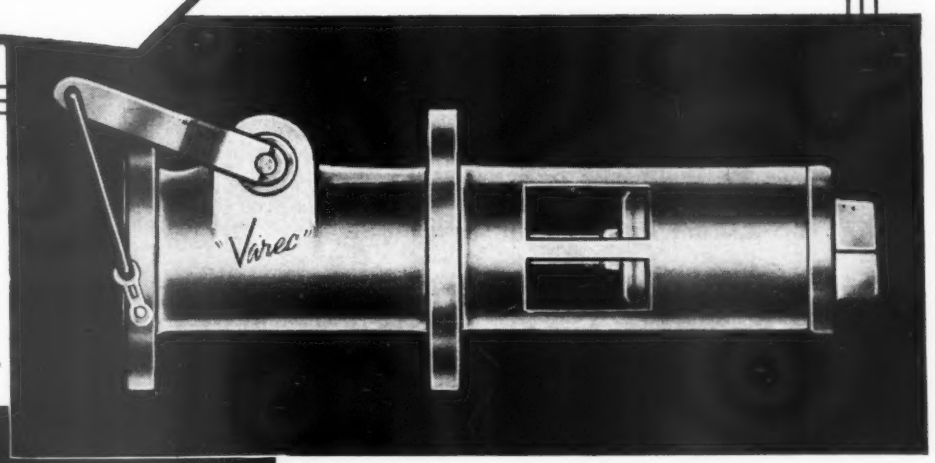
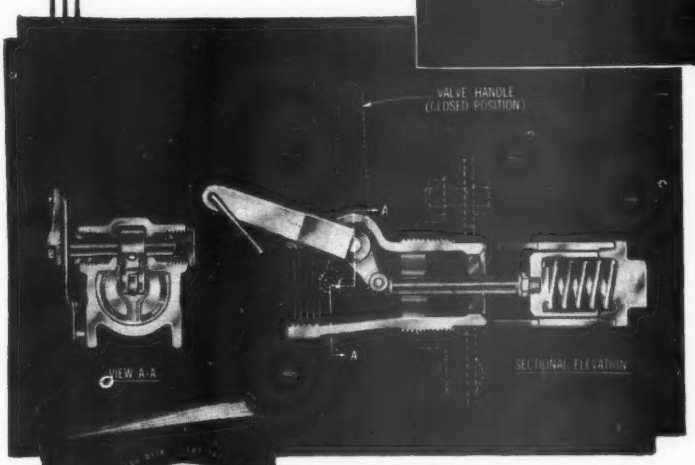
Right:—"Varec" approved Internal Safety Valve, Fig. No. 507, with Flanged Connections.

Below: — Cutaway view of "Varec" approved Internal Safety Valve, Fig. No. 506, with Screwed Connections.





"Varec" Catalog P-7 is now being distributed to executives, engineers, designers, and other personnel of refineries, petro-chemical plants, and other industries. It contains a wealth of information described by drawings, charts, photos, and engineering data. It is yours for the asking.

THIS Internal Safety Valve is designed to automatically close the flow into or from the tank in case of external fire exposure. The valve is spring-loaded and is held in its normal open position by a fusible link. On contact with fire, the link instantly melts. The valve then closes, insuring a positive shut-off.

To install a Swing Joint Assembly in conjunction with the Internal Safety Valve Special Swing Joint Adapters and Mounting Nozzles are available.

Standard construction is cast steel with bronze trim or all bronze. These valves are available in other materials upon special order.

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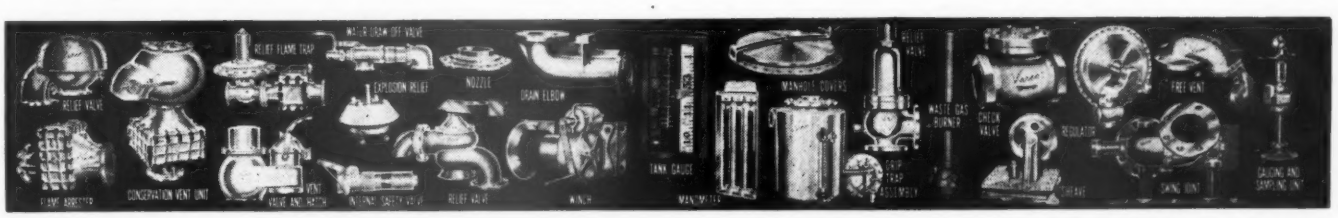


Experimental tests with hydraulic pressure applied to cement plugs in oil well casing

By WALDO MOORE, California Manager, The Cavins Company

CEMENT plugs are placed in oil well casing for several reasons, among which may be the isolating of one zone from another either permanently or temporarily, plugging back for testing, shutting off water, or closing off a damaged section of the well. The outlay for labor and material and the time required for placing the plug is comparatively small. If at any time it is desired to remove the plug it may be easily drilled up with relatively simple equipment and a minimum of time and labor. It does not require the use of rotary equipment for its destruction or fishing tools for the removal of the remnants. In some cases the loss of time involved in waiting for the cement to set up may rule against the choice of the cement plug. This will vary from 6 to 48 hr, depending upon the particular job to be done, the choice of materials, and the whim of the operator.

Waldo Moore

Many cement plugs are made in the well by using a lightweight aluminum-bodied bridging plug with canvas seal rings to prevent the cement from traveling down through the well fluid, and an off-bottom dump with full opening throat that unloads when the tool is started up the hole. This dump bottom is used as a setting tool for the drillable bridging plug and is attached to the lower end of one or more sections of pipe, usually a stand of tubing, which carries the load of cement and is run in on a sand line. It permits continuous dumping of cement with no loss of time as is required of dumps that must be set down on a solid bottom to unload. When cement is to be dumped with a conventional bottom-opening dump, which will fill up the casing in excess of 10 ft or thereabouts per trip, a time loss develops because of the necessity of having to wait for previous loads to set up sufficiently to give a solid footing on which to open the dump. For safety's sake it is not advisable to run any dump repeatedly into cement that is setting up.

The off-bottom dump was used on one abandonment job, with a three-man crew, to dump 205 sacks in a continuous operation to fill up approximately 1750 ft in 5¾-in. OD perforated casing. This type of dump with full opening throat is also used to spot chemical or place plastic material successfully, as the load is discharged in a solid slug out the bottom and is not jetted or squirted into the well fluid. Sand and gravel are also easily dumped with the same equipment. Experience has shown that the best results may be had if these last two materials are lubricated with sump oil or rotary mud to let them slide out of the bailer tubes easily.

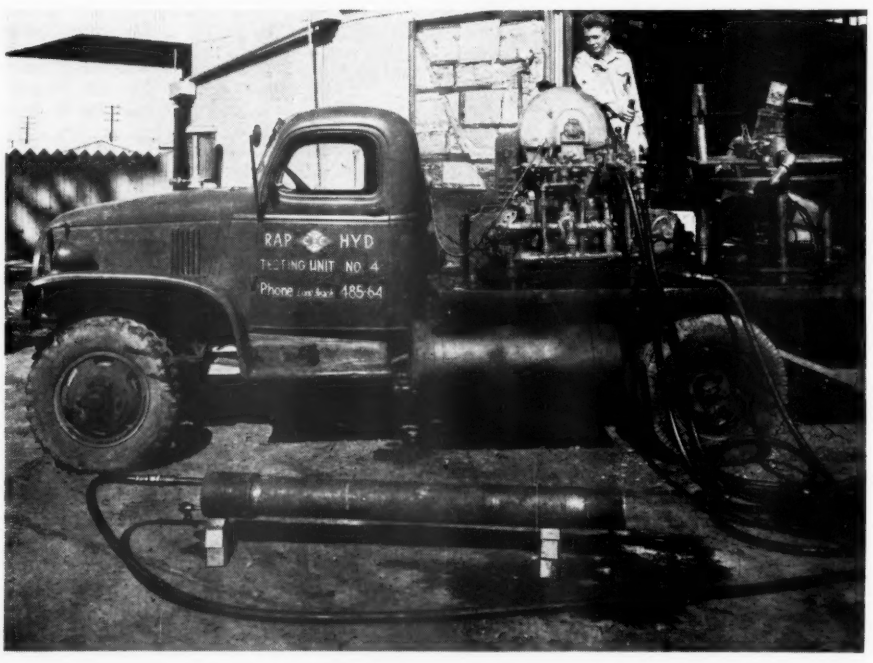
The several advantages of the cement plug regarding both installation and removal are well acknowledged, however, but little information was available on the size of the load or the amount of pressure that such a plug could be expected to carry without movement or leakage. To determine roughly what this is a series of shop tests were made. A discussion of the procedure and the results and a table of the findings follow.

Short sections of used oil well casing, selected at random and with no attention being given to weights other than to determine that they were within popular weight ranges, were stood on end and filled in varying amounts with a neat mixture of regular construction cement, which was mixed to weigh 123 lb per cu ft for all tests.

After the cement had set up in the casing, high pressure connections were attached to the open, or unfilled end. Connections were made to a motor-driven high pressure hydraulic tubing testing unit and fluid introduced into the unfilled chamber of the casing section, a vent valve in the upper end of which was left open until all air in the unfilled space of the casing section had been exhausted. This vent valve was then closed and the specimen to be tested was laid down horizontally so that any movement of the plug could be observed as the pressure was being applied.

The amount of pressure required to move the cement plug in the 4¾-in., 5½-in., and 6⅝-in. OD sizes seems to have increased with the length of the plug in a reasonably satisfactory degree. The pressure applied to the plugs in the 8⅝-in. OD size was in two cases not consistent with what might be desired. The cause of this has not been definitely determined but it may be assumed that the smooth interior surface of the pipe in these two instances was a major con-

High pressure hydraulic unit used for testing oil well tubing shown here connected to a test section of casing before applying pressure to cement plug.



* read what users have to say about BJ SPEED-TRIP POWER SLIPS

for drill pipe, casing and tubing

OVER 100 SPEED-TRIP Power Slips, handling 2⅜" through 7" tubing, drill pipe and casing, are now in operation with more than 30 different Operators. They are on drilling rigs in Texas, Oklahoma, Louisiana, Mississippi and California, Rocky Mountains, South America and the Middle East (operating simplicity makes them ideal for foreign operation with Native Crews).

MAJOR OIL COMPANIES are constantly reporting safer and speedier setting of casing strings with the *Speed-Trip* Power Slip. BJ *Speed-Trip* Power Slips can not only handle drill pipe and casing, but also tubing with *one set of slips*. This versatility is an economic asset as well as a safety factor.

OVER TWO YEARS of field service has proven this BJ engineered Oil Tool and, of course, all bugs have been eliminated. This tool is a *must* for every drilling rig. Easy to install and maintain, economical to operate.

Write for complete information

* Here's Proof! Here are samples of numerous voluntary reports from Drillers, Tool Pushers, Field Superintendents, etc.

SAVED AVERAGE OF 20 MINUTES PER ROUND TRIP

"...installed December, 1945. The slips to date have been used on 8 wells (in Permian Basin) averaging 240 round trips per well. We figure we have saved over 64 hours drilling time at over $40 per hour."

AVOIDED A FISHING JOB

"We were coming out of the hole with over 12,000 feet of 3½" drill pipe when a tool joint box collapsed and the pipe fell through the elevator at about the sixth girt. The Driller caught the pipe with your Speed-trip automatic slips without damage to the slips or the drill pipe, undoubtedly saving us a real fishing job."

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"We ran 5 combination strings of 7" O.D. casing over the last six months with each of our 5 BJ Power Slips. These strings ran from 6500 to 10,500 feet in length. The slips operated perfectly on every joint, and there was no slipping or marking of the pipe by the Power Slips."

BACK AND LEG INJURIES ELIMINATED

"Our Northern Division reports a survey of lost time rig injuries which indicates that the use of the BJ Speed-Trip Power Slips has completely eliminated back and leg injuries formerly experienced in handling old style hand slips. As you know, we have equipped each of our 4 rigs with the Slips."

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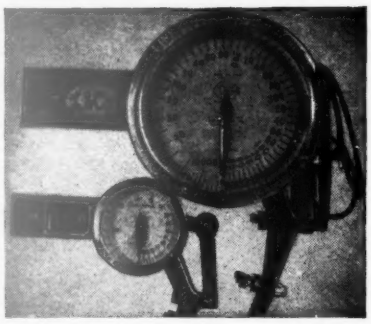

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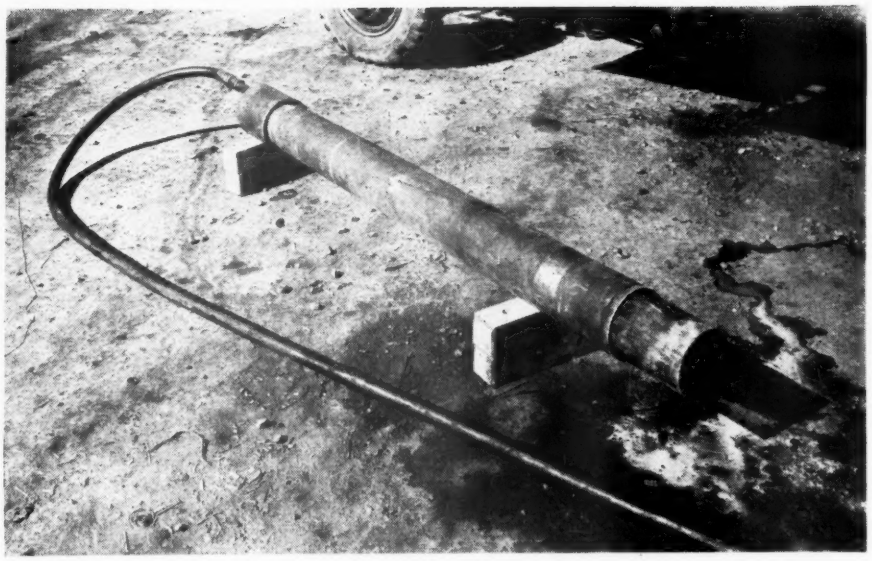

Test section of casing showing cement plug being forced out under hydraulic pressure.

OD pipe	Length of plug	Setting time	Psi required to move plug
4¾-in. blank	1 ft	48 hr	1000
4¾-in. blank	2 ft	48 hr	1900
4¾-in. blank	3 ft	48 hr	2500
4¾-in. blank	4 ft	48 hr	4000
5½-in. blank	1 ft	48 hr	1500
5½-in. blank	2 ft	48 hr	2600
5½-in. blank	3½ ft	48 hr	3200
5½-in. blank	5½ ft	48 hr	4000
6⅝-in. blank	1 ft	48 hr	500
6⅝-in. blank	2 ft	48 hr	1000
6⅝-in. blank	3 ft	48 hr	1300
6⅝-in. blank	4 ft	48 hr	1700
8⅝-in. blank	2 ft	120 hr	500
8⅝-in. blank	2 ft	96 hr	1200
8⅝-in. blank	3 ft	120 hr	900
8⅝-in. with collar recess	2 ft	144 hr	2000
8⅝-in. with collar recess	3 ft	144 hr	3000 (see notes)

tributing factor. All samples of the cement plugs were broken apart and examined after the tests were completed and found to be uniform.

Insofar as the cement gripping the inside of the casing sections is concerned, the test conditions may be considered as having been ideal, for the pipe was dry and no attempts were made to wet the pipe surface with oil or mud such as would be the case in most installations. On the other hand the test plugs did not have the benefit of the support of a fluid column on the underneath, or resistance side, which would likewise be the condition in most installations.

It may be of interest here to mention one recent plug installation in a well from which the owner wished to salvage some pipe. This well had practically no fluid in it and surrounding wells were pulling a vacuum on it. The plug had to be set a considerable distance above the fluid level, withstand the vacuum, and be of a type that could be removed with the minimum of trouble. The procedure was to set the drillable bridging plug in place with the off-bottom dump and then spot about 2 ft of sand and then 2 ft of cement on top of the bridging plug. The plug stayed in place and effectively shut off the vacuum. The next morning the casing was cut and pulled and the old drilling mud from between casing strings was bailed off the top of the plug. A plain bailer with chisel shoe was then used to break up the cement plug and the drillable bridging plug below after which the well was returned to production.

In the last two tests made in the 8⅝-in. OD size, a collar recess was provided in which the cement could lodge by screwing a collar and a short nipple below the piece of casing used for the tests so as to demonstrate the locking effect of collar recesses. In the last test made, which was in the 8⅝-in. OD size, the high pressure connections blew out at 3000 psi but the plug had not moved at this pressure.

After the plugs began to move there was a decline in the pressure required to keep the plug moving, as it was being ejected from the open end of the casing nipple and thereby diminishing the area in contact with the casing. This decrease in pressures appeared to be reasonably constant except in a few instances when the fluid channeled by the cement plug and the pressures and the rate of ejection were difficult to observe or control.

It should perhaps be called to the reader's attention that circumferential areas (wall area of contact between plug and casing) do not increase in the same proportion as cross-sectional areas for any given length of plug. No tabulation was made of the total weight put against the plug or its equivalent in a standing column of fluid, but these may be arrived at from the column under "Psi required to move plug". ★ ★ ★

☆ ☆ ★

Sinclair Oil Corporation suspended operations in Ethiopia in January because of clashes in neighboring Somaliland. Disturbances were said to be at Magadiscio, Indian Ocean port that is the company's port of entry.

the Petroleum Engineer's

CONTINUOUS TABLES

a daily reference for operating men

INSTALLMENT No. 128

A valuable and regular feature of *The Petroleum Engineer*, the Continuous Tables, now in their eleventh year of publication, were designed to save time and effort for the technician and the practical field or plant worker. The tables have proved one of the most popular and helpful departments of *The Petroleum Engineer*. Data are presented in the simplest form available with many types of information included that are best presented by curves or nomographs when three or more variables must be considered simultaneously.

The Continuous Tables have been developed as a result of suggestions for new tables, direct contributions and improvements to existing tables by members of the petroleum and related industries, including manufacturing concerns, who are continually searching for practical information reduced by computation to tabular form readily applicable to the problems daily confronting them that might otherwise necessitate a more or less tedious calculation. These contributions and suggestions from the industry have resulted in a valuable exchange of information and data contributing to the progress of the industry as a whole.

This index will be revised monthly. The index for installments 1-12, inclusive, will be found in the May, 1938, issue; 13-24, inclusive, in the June, 1939, issue; 25-36, inclusive, in the June, 1940, issue; 37-48, inclusive, in the June, 1941, issue; 48-60, inclusive, in the June, 1942, issue; 61-72, inclusive, in the June, 1943, issue; 73-79, inclusive, in the January, 1944, issue; 80-82, inclusive, in the April, 1944 issue; 83-85, inclusive, in the July, 1944, issue; 86-88, inclusive, in the October, 1944, issue; 89-91, inclusive, in the January, 1945, issue; 92-94, inclusive, in the April, 1945, issue; 95-97, inclusive, in the July, 1945, issue; 98-100, inclusive, in the October, 1945, issue; 101-103, inclusive, in the January, 1946, issue; 104-106, inclusive, in the April, 1946, issue; 107-109, inclusive, in the July, 1946, issue; 110-112, inclusive, in the October, 1946, issue; 113-115, inclusive, in the January, 1947, issue; 116-118, inclusive, in the April, 1947, isisue; 119-121, inclusive, in the July, 1947, issue; 122-124, inclusive, in the October, 1947, issue; 125-127, inclusive, in the January, 1948, issue.

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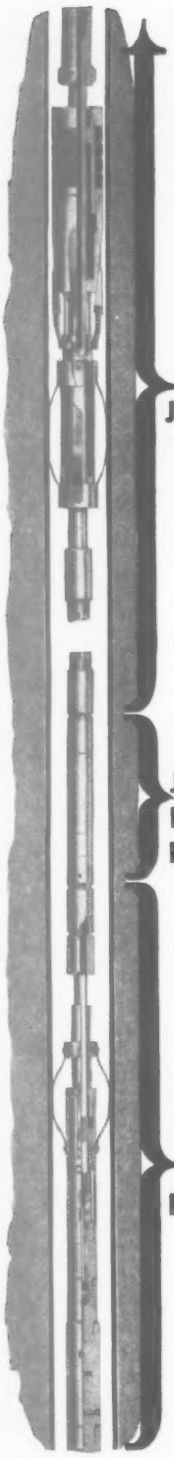
SHOOT-N-TEST

THE JOHNSTON *all purpose* GUN PERFORATOR



Gives you maximum PORTABILITY!

THE JOHNSTON GUN PERFORATOR is flexible in operation and so completely portable that the entire unit can be transported in your regular field car! For each perforating job you need only the Firing Head and the Perforating Gun Sections—no special depth measuring devices, firing equipment or extra assembling tools are necessary.

After delivering the Johnston Gun Perforator to the well, you can select the exact number of Perforating Gun Sections needed for the job. When the quantity of perforations is known, you simply attach the correct number of Perforating Gun Sections to the Firing Head and lower the entire unit on the bottom joint of tubing or drill string to the zone selected for perforation. Bottom-hole hydrostatic pressure fires the Johnston Gun Perforator automatically following definite rotary and vertical manipulation of the connecting string by the driller.

And if you want a formation and pressure test made on the same run of tubing or drill string, you simply connect the Johnston Gun Perforator to *your* regular Johnston Formation Tester and Pressure Recorder for *combined* perforate-and-test operations. It's the slickest possible way of obtaining water shut-off information, doing exploratory work or testing for actual production.

FLEXIBILITY and PORTABILITY

are only two of the *many* outstanding advantages of the Johnston "SHOOT-N-TEST" All Purpose Gun Perforator. Here are other important Johnston features to consider when contemplating Gun Perforator equipment . . .

SAFE gun perforator operation! The Johnston Gun Perforator will not fire until subjected to *both* in-the-hole hydrostatic pressure and positive rotary and vertical manipulation of the pipe string by the driller.

POSITIVE FIRE of all projectiles! The safe, fool-proof hydrostatic firing principle of the Johnston Gun Perforator coupled with the flash-hole design of the Perforating Gun Sections assures positive fire of all projectiles.

ANY NUMBER OF PERFORATIONS possible! Any number of four, five or six-shot Perforating Gun Sections can be attached to the Johnston Gun Perforator Firing Head to provide the *exact* quantity of perforations needed for each job.

EXACT POSITIONING in producing zone! Accurate placement of the Johnston Gun Perforator at the *exact* depth for perforating is easily determined by pipe-in-the-hole tally. No rigging-up of special measuring devices is necessary.

MINIMUM OF EXPENDABLE SUPPLIES! The Johnston Gun Perforator needs only a minimum of loading supplies for each perforating job. The Perforating Gun Sections require only seals, powder charges and projectiles for reloading.

FAST, EASY MAINTENANCE! The Johnston Gun Perforator is outstanding for its simplicity of operation and trouble-free construction. The simple procedure of disassembly, cleaning, loading and reassembly can be done right on the rig floor.

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On The Johnston "SHOOT-N-TEST" Gun Perforator!

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PLATE EFFICIENCY OF FRACTIONATING COLUMNS AND ABSORBERS

● **Introduction.** An important phase in the design of plate-fractionating columns and absorbers is the determination of the number of plates required in the column. The number of theoretical (or perfect) plates can be calculated by known methods[1, 2, 19, 20] but such a calculation involves the assumption that the vapor and liquid leaving the plate are in equilibrium. As this condition is rarely obtained, the number of theoretical plates must be divided by the plate efficiency in order to obtain the number of actual plates required.

Plate efficiency may be expressed in several ways.

1. Overall plate efficiency. This is the ratio of the number of equilibrium contacts (theoretical plates) to the number of actual plates.

2. Murphree plate efficiency. This expresses the efficiency for a single plate as follows:

$$E_{mv} = \frac{Y'_i - Y'_o}{Y'_i - Y'^*} \quad . \quad . \quad . \quad . \quad . \quad (1)$$

Where:

Y'_i = mole fraction of more volatile component in the vapor phase of the total vapor entering the plate.

Y'_o = mole fraction of more volatile component in the vapor phase of the total vapor leaving the plate.

Y'^* = mole fraction of more volatile component in the vapor phase in equilibirum with the liquid leaving the plate.

3. Point efficiency. This is the efficiency at a single point on the plate.

The Murphree plate efficiency assumes that the liquid on each plate is completely mixed and that all the vapor comes in contact with liquid of the same composition as that leaving the plate. This is not the case because there is incomplete mixing of the liquid as it flows across the plate. Also, the vapor that passes through the caps near the inlet weir comes in contact with a liquid richer in the more volatile components than the liquid leaving the plate. Thus, it is possible to have a vapor leaving the plate richer in the more volatile component than the equilibrium concentration with the leaving liquid. For this case, Murphree plate efficiencies more than 100 per cent can be obtained.

The overall plate efficiency in most cases would fall between the Murphree plate efficiency and the local or point efficiency. The correlations presented in this paper are based on overall plate efficiencies. However, for some cases it was necessary to derive overall plate efficiency from Murphree plate efficiencies.

TABLE 1. Plate efficiency of fractionation column.

Type of column	Lit. ref. no.	Symbol	Average column		Key components		α Rel. volatility	μ Viscosity of feed, average column conditions, centipoises	$\alpha\,\mu$	Plate eff., per cent
			Temp., F	Pressure, psia	High volatility	Low volatility				
1. Gasoline fractionator	3	0	197	215	Isobutane	Butane	1.36	0.10	0.14	74.0
2. Gasoline fractionator	3	0	217	265	Isobutane	Butane	1.31	0.09	0.12	88.0
3. Gasoline fractionator	3	0	200	218	Isobutane	Butane	1.28	0.10	0.13	86.0
4. Gasoline fractionator	3	0	205	223	Isobutane	Butane	1.28	0.10	0.13	83.0
5. Naphtha fractionator test 1	15	0	240	135	Isopentane	Pentane	1.21	0.15	0.18	63.0
6. Naphtha fractionator test 2	15	0	236	125	Isopentane	Pentane	1.21	0.16	0.19	69.0
7. Naphtha fractionator test 3	15	0	214	125	Butane	Pentane	2.20	0.15	0.33	67.4
8. Naphtha fractionator test 4	15	0	157	100	Butane	Pentane	2.61	0.22	0.57	51.0
9. Cracking unit stabilizer	8	0	315	347	Propane	Butane	1.76	0.07	0.13	84.0
10. Cracking unit stabilizer	8	0	309	363	Butane	Pentane	1.88	0.10	0.18	77.0
11. Cracking unit stabilizer	8	0	312	357	Propane	Butane	1.77	0.07	0.12	83.0
12. Cracking unit stabilizer	8	0	319	363	Propane	Butane	1.81	0.11	0.19	81.0
13. Cracking unit stabilizer	8	0	313	366	Propane	Butane	1.77	0.09	0.16	84.2
14. Cracking unit stabilizer	8	0	314	350	Propane	Butane	1.83	0.10	0.18	80.0
15. Poly plant stabilizer	8	0	198	362	Propane	Butane	2.11	0.22	0.47	55.0
16. Poly plant stabilizer	8	0	228	365	Propane	Butane	2.00	0.22	0.44	58.0
17. Butane depropanizer	8	0	162	235	Propane	Butane	2.45	0.15	0.36	68.0
18. Butane propanizer	8	0	161	235	Propane	Butane	2.45	0.17	0.42	64.0
19. Debutanizer	8	0	275	117	Butane	Pentane	2.00	0.17	0.33	59.0
20. Deisopentanizer	8	0	280	116	Pentane	Hexane	1.90	0.16	0.30	64.0
21. Deisopentanizer	8	0	270	116	Pentane	Hexane	1.96	0.17	0.34	62.0
22. Deisopentanizer	8	0	262	116	Pentane	Hexane	1.98	0.16	0.31	67.7
23. Deisopentanizer	8	0	264	115	Pentane	Hexane	1.87	0.16	0.30	69.0
24. Deisopentanizer	8	0	260	117	Pentane	Hexane	1.97	0.15	0.30	73.0
25. Deisopentanizer	8	0	304	367	Isobutane	Butane	1.16	0.11	0.13	76.7
26. Deisopentanizer	8	0	253	98	Isopentane	Pentane	1.22	0.19	0.24	59.5
27. Stablization of ethylene dichloride	22	Δ	206	21	Water	Ethylene Dichloride	20.51	0.37	7.60	29.0
28. Stabilization of ethylene dichloride*	22	Δ	220	28	Water	Ethylene Dichloride	16.0	0.35	5.60	29.0
29. Stabilization of ethylene dichloride*	22	Δ	220	28	Ethyl chloride	Ethylene Dichloride	3.1	0.35	1.08	57.0
30. Stabilazition of ethyl chloride	22	Δ	173	151	Isobutane	Ethyl Chloride	1.69	0.11	0.19	85.0
31. Alcohol-water, lab. column	12	×	196	14.7	Ethyl alcohol	Water	9.03	0.32	2.89	32.0
32. Alcohol-water, lab. column	12	×	188	14.7	Ethyl alcohol	Water	7.05	0.36	2.54	47.0
33. Alcohol-water, lab. column	12	×	179	14.7	Ethyl alcohol	Water	2.34	0.42	0.98	77.0
34. Alcohol-water, lab. column	12	×	174	14.7	Ethyl alcohol	Water	1.27	0.45	0.57	62.0
35. Beer stills (perforated trays)	11	+	208	16	Ethyl alcohol	Water	10.8	0.32	3.46	41.0
63. Beer stills (perforated trays)	11	+	210	17	Ethyl alcohol	Water	10.8	0.32	3.46	42.5
37. Alcohol-water	17	+	200	15	Alcohol	Water	9.0	0.29	2.61	49.0
38. Trichloroethylene toluene and water, lab. column	18	□	210	15	Trichloro-ethylene	Toulene	2.12	0.30	0.635	53.0

*Results of one test with plate efficiency based on different components.

● **Factors affecting plate efficiency.** The plate efficiency of fractionating columns and absorbers is affected by both the mechanical design of the column and the physical properties of the solution.

Mechanical design. The following variables in mechanical design have been studied by others.

The vapor velocity in the column affects plate efficiency in that (as shown by Peavy and Baker[16]) the efficiency at low velocities increases with vapor velocity; at moderated velocities, remains constant for a considerable range; and then at high velocities, drops off as entrainment becomes pronounced. The optimum velocity for maximum plate efficiency can be obtained from the correlation of Brown and Souders[4] supplemented by the work of Brown and Lockhart.[3]

The plate efficiency of a column increases as the submergence of the slots is increased and is independent of slot velocity for the range of velocities commonly employed. This is shown by Carey et al.[6]

Adequate downcomer area and length must be provided to handle the liquid load and thus prevent column flooding. The method of calculation of downcomer size is summarized by Kirkbride.[13] In addition, for large diameter columns with high liquid loads, adequate provision must be made to insure plate stability. An unstable plate results when the liquid head at the entrance to the plate is considerably greater than the head at the discharge from the plate. With this condition, there is a tendency for the vapor to pass through only those caps with a low-liquid head. Good et al[10] have presented a correlation to determine the allowable liquid load in the column for stable plate operation.

The diameter of the column does not affect plate efficiency for diameters less than 5 ft. However, for columns larger than 7 ft, the length of the liquid path (cross flow effect) must be taken into account.

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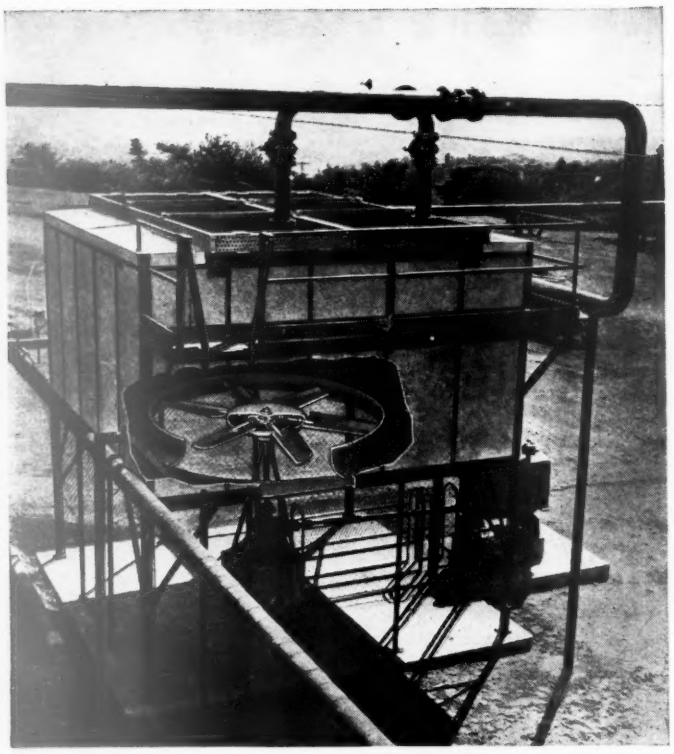

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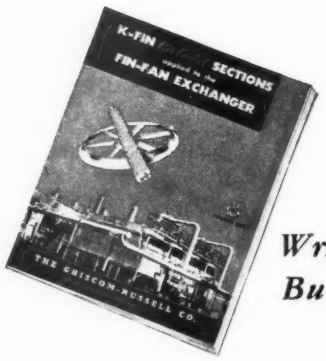

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INTERPRETATION OF WELL TEST DATA IN GAS-CONDENSATE FIELDS

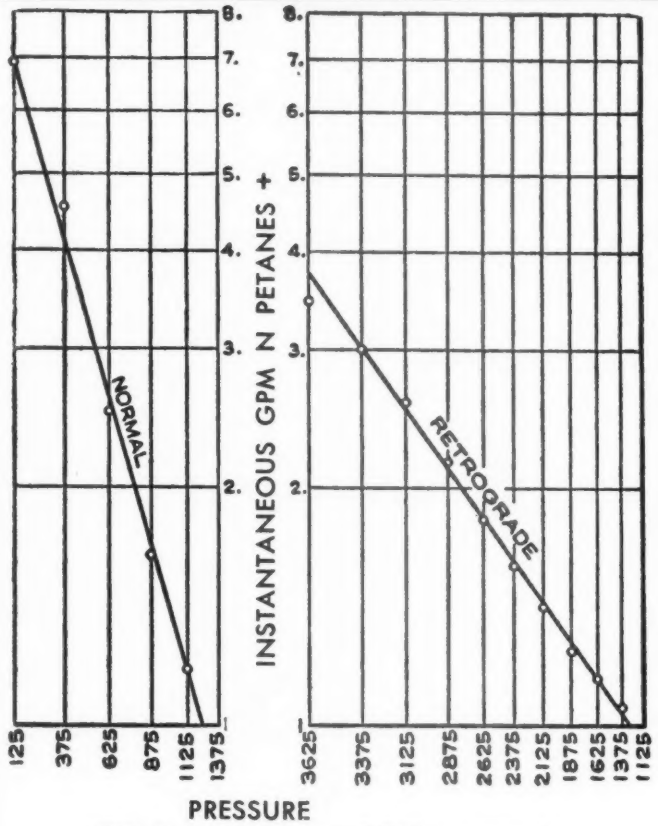

FIG. 7. Instantaneous G.P.M. retrograde curve from Fig. 4. Plotted logarithmically.

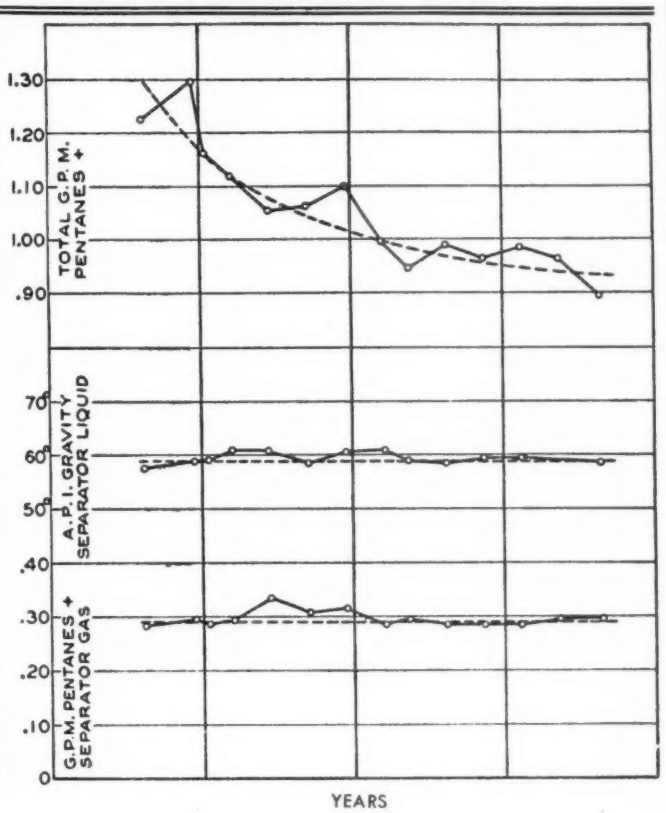

FIG. 8. Plot of average G.P.M. data for 19 wells in LaGloria field, Texas.

In Fig. 7, the two legs of curve B are plotted on logarithmic paper, the retrograde leg being plotted against reduced pressures and the normal leg against pressure gains, constants being added to both to straighten them out. Both reach approximately the same G.P.M. near 1250 psi, which may be taken as the point of convergence.

In Fig. 8 are shown the average records of 19 wells over a period of three years in the La Gloria field, Texas. Curves are shown for the total G.P.M., the API gravity of the separator liquid and the G.P.M. of the separator gas.

Figs. 9 and 10 are the records of two wells in different reservoirs in the La Gloria field. The entry of dry gas into these two wells is shown by the declines in separator gas G.P.M. and separator liquid gravity. That dry gas has reached the wells is confirmed by the calculated area filled by injected residue gas. The two records show how unreliable an indicator is the total G.P.M. From it alone, it cannot be told whether the loss in G.P.M. is due to retrograde condensation, to dilution, or to some other cause.

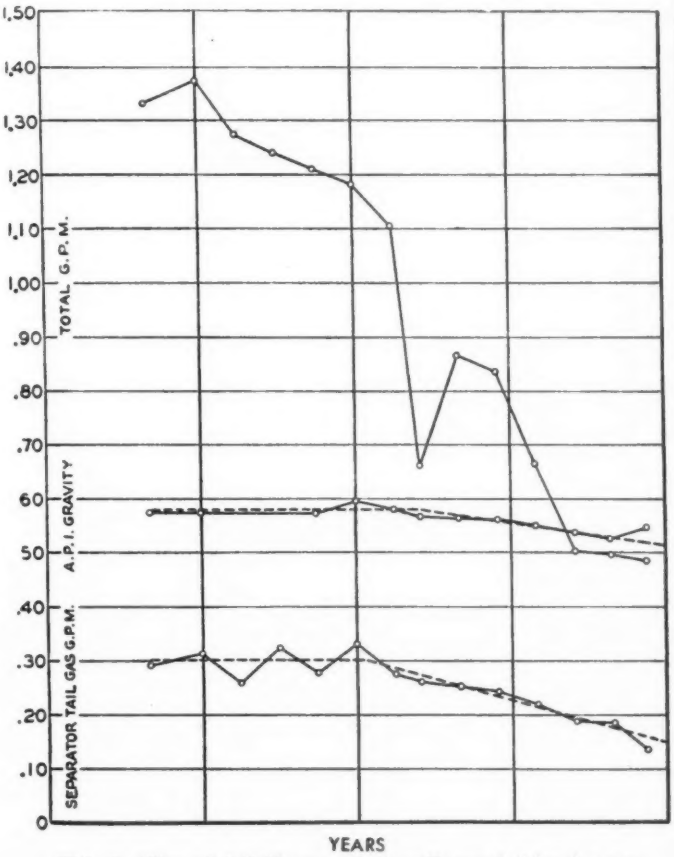

FIG. 9. Plot of G.P.M. record of well invaded by dry gas.

Taken from the article, "Interpretation of Well Test Data in Gas-condensate Fields," by James O. Lewis that was presented before American Institute of Mining and Metallurgical Engineers, Chicago, Illinois, February 1946. Published in *Petroleum Technology*, July, 1946. Published in *The Petroleum Engineer*, September, 1947, pages 180 to 202, inclusive.

NOTE: References are shown on the last sheet in this series of tables.

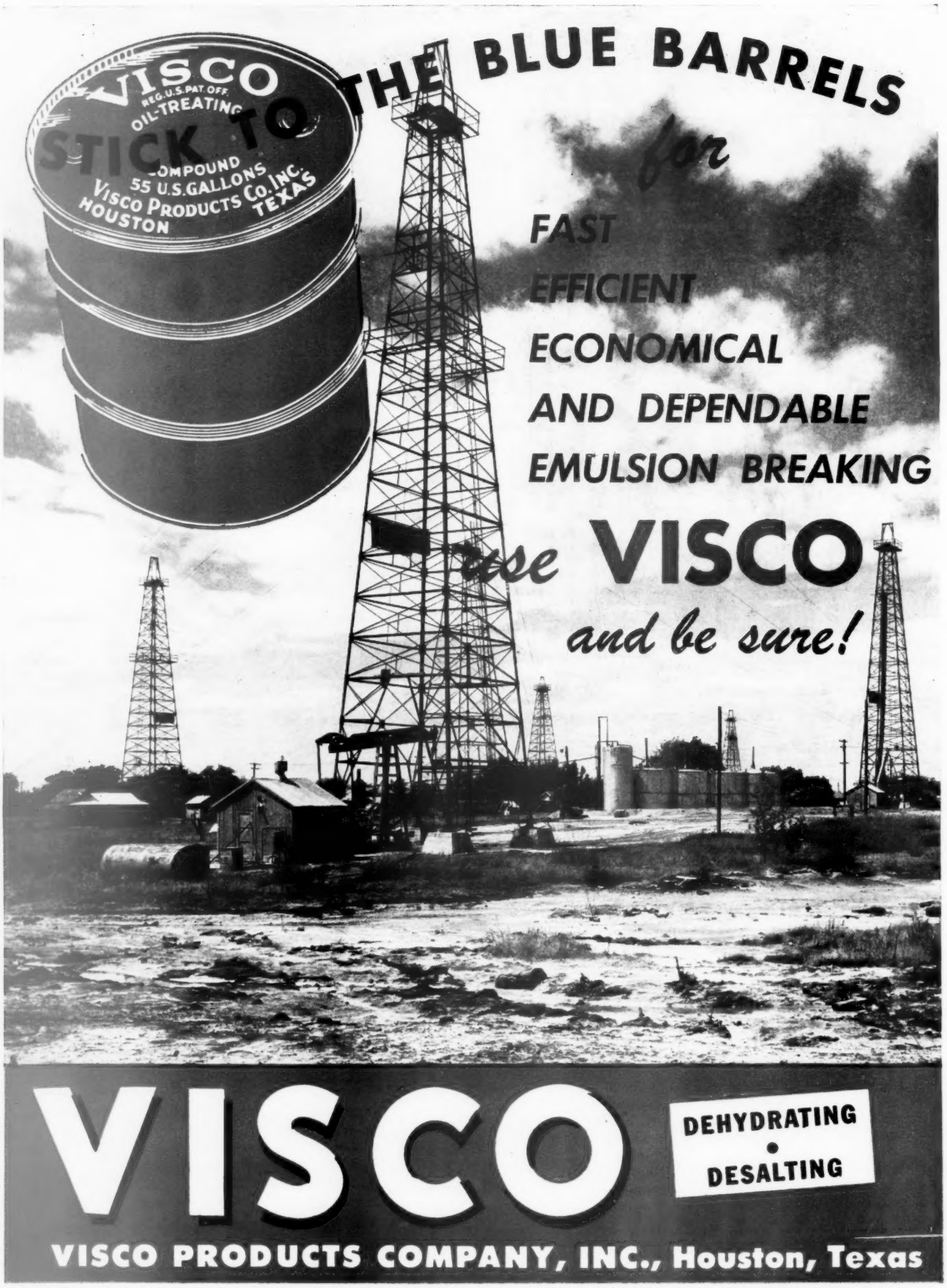

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PLATE EFFICIENCY OF FRACTIONATING COLUMNS AND ABSORBERS

Physical properties. The effect of physical properties of the solution on plate efficiency has not been studied as extensively as the mechanical-design features. Yet, the importance of physical properties has been shown by plate efficiencies varying from approximately 0 to 100 per cent in columns with similar mechanical designs. There have been only a few studies on the effect of physical properties on the plate efficiency.

Walter and Sherwood[23] conducted laboratory experiments on the absorption and desorption of carbon dioxide in water and glycerol solutions, the absorption of ammonia in water, and the absorption of hydrocarbons in oil. They showed that the plate efficiency increased with increasing solubility of the gas in the dissolving medium and with decreasing viscosity of the dissolving medium. Keyes and Byman[12] studied the system alcohol-water in a laboratory column and showed the effect of alcohol concentration on plate efficiency and indicated the effect of viscosity.

Gerster, Koffolt, and Withrow[9] showed that their $(PTU)_{ov}$, number of actual plates per number of transfer units, is a function of the slope of the equilibrium curve and the reflux ratio. For the special case where the number of transfer units is equal to the theoretical plates, it follows that the plate efficiency is a function of the slope of the equilibrium curve and the reflux ratio.

The most comprehensive study from a practical standpoint was made by Drickamer and Bradford[8] who showed that for commercial hydrocarbon fractionating columns and absorbers, the plate efficiency increased with decreasing viscosity. Drickamer and Bradford's correlation avoids the limitations of the other studies which were made in laboratory columns but has the disadvantage that it is suitable only for hydrocarbon separations with a low relative volatility of the key components.

The purpose of this investigation is to correlate plate efficiency with the physical properties of the material handled, the resulting correlation to be free of the limitations of the correlations mentioned. As a matter of convenience, separate correlations are presented for fractionating columns and absorbers, although the factors affecting both are in essence the same and could be presented in the same correlation.

● **Plate efficiency of fractionating columns.** The plate efficiency of fractionating columns was correlated (Fig. 1) as a function of the product of the relative volatility of the key components* and the average molal liquid viscosity (in centipoises) of the column feed, both at the average tower temperature and pressure. The data for the correlations were obtained from tests reported in the literature on 29 commercial columns and five laboratory columns and from three unpublished tests on commercial columns. The data for all the tests are summarized in Table 1. Complete data for the unpublished tests are presented in Table 3.

Efficiencies for all tests were overall plate efficiencies and for most of the tests these were readily obtainable; however, for the laboratory tests on the alcohol-water column,[12] tests 31 to 34 in Table 1, the overall plate efficiency was obtained by assuming it to be between the reported Murphree and point efficiencies. This appears to be a reasonable assumption since these efficiencies compare favorably with overall plate efficiencies obtained in a commercial fractionation column with ethyl alcohol. Other laboratory data, for example the work of Peavy and Baker[16] on ethyl alcohol-water system, were not included.

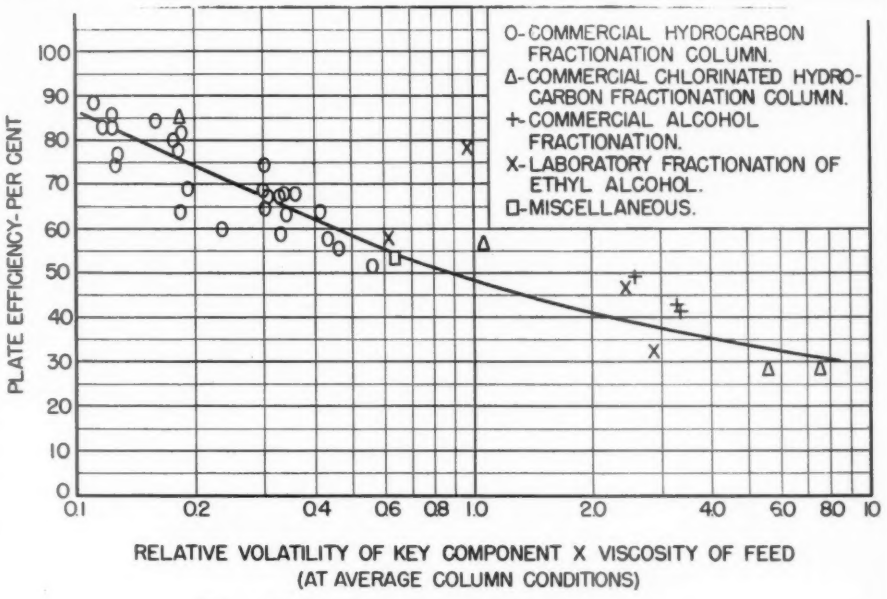
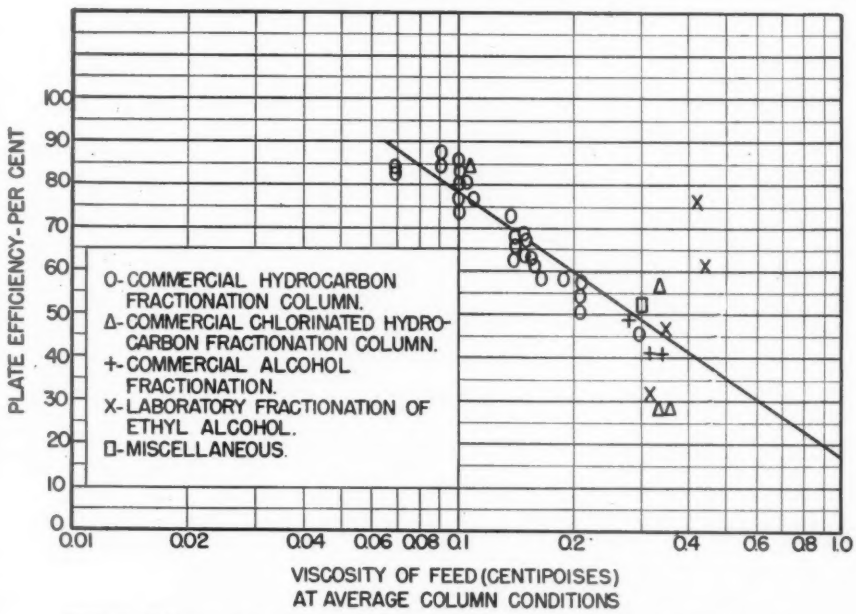

O-COMMERCIAL HYDROCARBON FRACTIONATION COLUMN.
Δ-COMMERCIAL CHLORINATED HYDROCARBON FRACTIONATION COLUMN.
+-COMMERCIAL ALCOHOL FRACTIONATION.
X-LABORATORY FRACTIONATION OF ETHYL ALCOHOL.
□-MISCELLANEOUS.
PLATE EFFICIENCY-PER CENT
RELATIVE VOLATILITY OF KEY COMPONENT X VISCOSITY OF FEED (AT AVERAGE COLUMN CONDITIONS)

FIG. 1. Effect of relative volatility and viscosity on plate efficiency of fractionating columns.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Δ-COMMERCIAL CHLORINATED HYDROCARBON FRACTIONATION COLUMN.
+-COMMERCIAL ALCOHOL FRACTIONATION.
X-LABORATORY FRACTIONATION OF ETHYL ALCOHOL.
□-MISCELLANEOUS.
PLATE EFFICIENCY-PER CENT
VISCOSITY OF FEED (CENTIPOISES) AT AVERAGE COLUMN CONDITIONS

FIG. 2. Effect of viscosity on plate efficiency of fractionating columns.

*Key components are those for which definite limiting concentrations have been specified in the overhead and bottoms.

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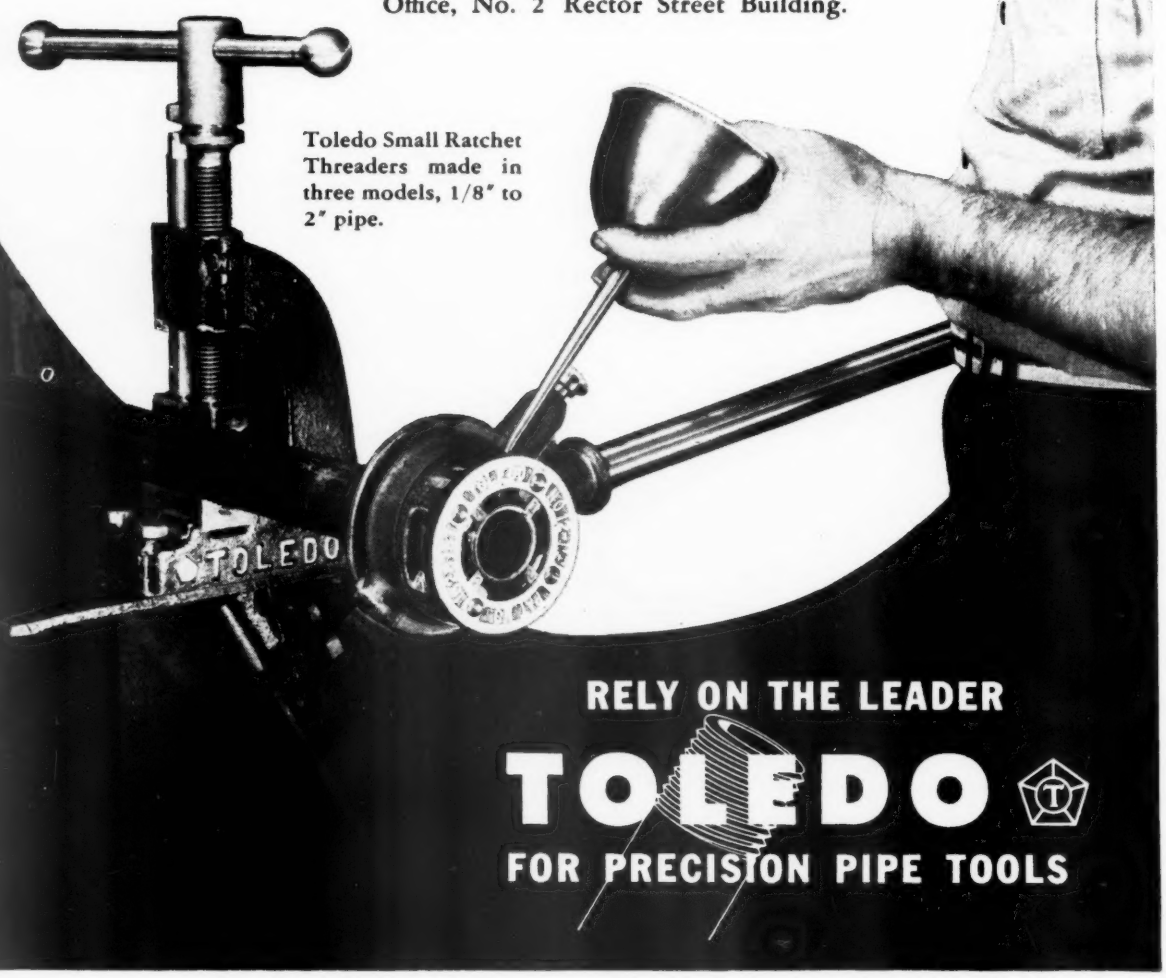

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PLATE EFFICIENCY OF FRACTIONATING COLUMNS AND ABSORBERS

Viscosity and relative volatility were selected as the most important physical properties affecting plate efficiency for the following reasons:

1. The effect of viscosity on plate efficiency has been shown by Drickamer and Bradford, who presented a correlation of plate efficiency with viscosity for hydrocarbon separations of about the same relative volatility. This is a logical relationship, inasmuch as the mass transfer of vapors and liquids is a function of viscosity as shown by Chilton and Colburn[7] and Walter and Sherwood.[28]

2. The effect of relative volatility was shown by the results of a test on an ethylene dichloride stabilizer. (Table 3). In this column, the feed contained both water and ethyl chloride which had to be reduced to low concentrations in the ethylene dichloride bottoms. The plate efficiency based on water as the low-boiling key component (ethylene dichloride the high-boiling key component) was 29 per cent and the relative volatility between water and ethylene dichloride was 16. The plate efficiency based on ethyl chloride as the low-boiling key component was 57 per cent and the relative volatility between ethyl choloride and ethylene dichloride was 3.1. No theoretical explanation for this relationship has been found.

The agreement between test results (Table 1) and the fitted curve for these data (Fig. 1) was good. Average deviation was ± 10 per cent and 90 per cent of the data fell within ± 16 per cent of the predicted curve. Only one point, obtained from a laboratory test on an ethyl alcohol-water separation, deviated more than 30 per cent from the curve and was believed to be in error. The deviations from the curve are to be expected from errors in analyses, inaccuracies in physical data, and limitations in the method of calculation. In addition, differences in column design could account for some of the deviation.

The plate efficiency was plotted against the viscosity of the feed in Fig. 2, as suggested by Drickamer and Bradford. This gave practically as good an agreement between actual and predicted efficiency as obtained in Fig. 1. This is to be expected because most of the tests are for systems of similar relative volatilities. however, for the tests where the relative volatility is high (Points +, ×, and △ on Figs. 1 and 2), this paper (Fig. 1) gave a better correlation.

● **Plate efficiency of absorbers.** The plate efficiency of absorbers was correlated (Fig. 3) as a function of the term HP/μ

Where:

H = Henry's law constant in lb moles per (cu ft) (atm),

P = pressure in atm,

μ = viscosity of absorbent in centipoises.

TABLE 2. Plate efficiency of absorbers.

Type of column	Lit. ref. no.	Symbol	Average column Temp., F.	Average column Pressure, psia	Key component	HP*	μ Liquid viscosity, centipoises	HP/μ	Plate eff., per cent
1. Poly plant absorber	8	A	127	260	Butane	0.85	0.41	2.07	39.0
2. Poly plant absorber	8	A	124	265	Butane	0.94	0.50	1.96	38.0
3. Poly plant absorber	8	A	126	255	Butane	0.78	0.41	1.94	42.0
4. Poly plant absorber	8	A	120	260	Butane	0.87	0.48	1.76	36.0
5. Absorber	8	A	132	254	Butane	0.96	0.31	3.10	50.0
6. Absorber	8	A	138	267	Butane	0.92	0.22	4.13	56.4
7. Absorber	8	A	117	94	Butane	0.32	1.41	0.22	10.4
8. Absorber	5	A	93	485	Isopentane	5.16	0.42	12.28	50.0
9. Cracking coil gas absorber†	19	A	60	92	Ethylene	0.04	1.90	0.02	10.3
10. Cracking coil gas absorber†	19	A	60	92	Ethane	0.06	1.90	0.03	14.9
11. Cracking coil gas absorber†	19	A	60	92	Propylene	0.20	1.90	0.11	25.5
12. Cracking coil gas absorber†	19	A	60	92	Propane	0.22	1.90	0.11	26.8
13. Cracking coil gas absorber†	19	A	60	92	Butylene	0.61	1.90	0.32	33.8
14. Absorption of propylene in heavy naphtha in a 2-in. column	23	C	75.2	66	Propylene	0.15	1.00	0.15	24.0
15. Absorption of propylene in heavy naphtha in a 2 in. column	23	C	109.4	66	Propylene	0.10	0.74	0.13	21.6
16. Absorption of propylene in heavy naphtha in a 2-in. column	23	C	69.8	46	Propylene	0.12	1.05	0.10	22.6
17. Absorption of isobutylene in heavy naphtha in a 2-in. column	23	C	78.8	66	Isobutylene	0.54	0.97	0.56	36.4
18. Absorption of propylene in gas oil in a 2-in. column	23	C	75.2	66	Propylene	0.12	5.50	0.02	11.0
19. Absorption of propylene in gas oil in a 2-in. column	23	C	118.4	66	Propylene	0.07	2.80	0.03	13.1
20. Absorption of isobutylene in gas oil in a 2-in. column	23	C	77.0	66	Isobutylene	0.39	5.40	0.07	17.4
21. Absorption of isobutylene in gas oil in a 2-in. column	23	C	86.0	66	Isobutylene	0.33	4.80	0.07	17.1
22. Absorption of isobutylene in gas oil in a 2-in. column	23	C	98.6	66	Isobutylene	0.27	3.90	0.07	17.6
23. Absorption of propylene in gas lube oil in a 2-in column	23	C	73.4	66	Propylene	0.08	21.50	0.004	10.6
24. Absorption of propylene in gas lube oil in a 2-in. column	23	C	105.8	66	Propylene	0.05	10.50	0.005	4.7
25. Absorption of isobutylene in gas lube oil in a 2-in. column	23	C	75.2	66	Isobutylene	0.32	20.60	0.02	10.1
26. Absorption of isobutylene in gas lube oil in a 2-in. column	23	C	75.2	66	Isobutylene	0.32	20.60	0.02	9.2
27. Absorption of carbon dioxide in water in an 18-in. column (avg. of 7 runs)	23	B	50.4	14.7	Carbon dioxide	0.003	1.30	0.002	2.0
28. Desorption of carbon dioxide in water in a 5-in. column (avg. of 32 runs)	23	B	78.6	14.7	Carbon dioxide	0.002	0.88	0.002	2.4
29. Desorption of carbon dioxide in 12.2 weight per cent glycerol in a 5-in. column	23	B	77.0	14.7	Carbon dioxide	0.002	1.21	0.002	1.6
30. Desorption of carbon dioxide in 23.6 weight per cent glycerol in a 5-in. column	23	B	77.0	14.7	Carbon dioxide	0.002	1.71	0.001	0.96
31. Desorption of carbon dioxide in 33.2 weight per cent glycerol in a 5-in. column	23	B	77.0	14.7	Carbon dioxide	0.001	2.36	0.0004	0.96
32. Desorption of carbon dioxide in 43.7 weight per cent glycerol in a 5-in. column	23	B	77.0	14.7	Carbon dioxide	0.001	3.74	0.0003	0.65
33. Absorption of ammonia in water	23	D	57.0	14.7	Ammonia	5.80	1.17	4.96	69.0

*$HP = \frac{\text{sp. gr. of liquid in lb/cu ft}}{\text{equilibrium vaporization constant of key component} \times \text{molecular weight of liquid}}$

†Results of one test with plate efficiency based on different components.

All values are taken at average column conditions.

The data were obtained from tests reported in the literature on 13 commercial columns and 20 laboratory columns. These data are summarized in Table 2.

The efficiencies for the commercial absorbers were overall plate efficiencies, but, unfortunately the efficiencies for the laboratory columns were Murphree plate efficiencies; however, it was assumed that the Murphree plate efficiencies were equal to the overall plate efficiencies. This assumption was based on:

1. Data on absorption of hydrocarbons in oil in the laboratory columns gave Murphree efficiencies equal to the overall plate efficiencies obtained in commercial columns for similar systems.

2. The laboratory data were obtained in small columns where there is little difference in the Murphree plate efficiency and point efficiency. For this condition, the Murphree plate efficiency most likely approaches that of the overall plate efficiency. However, two of the tests were run in an 18-in. column and one of the tests, the absorption of ammonia in water, gave a Murphree plate efficiency of 69 per cent, which was higher than the overall plate efficiency predicted in Fig. 3. This was expected since Murphree plate efficiencies are usually larger than overall plate efficiencies in large columns.

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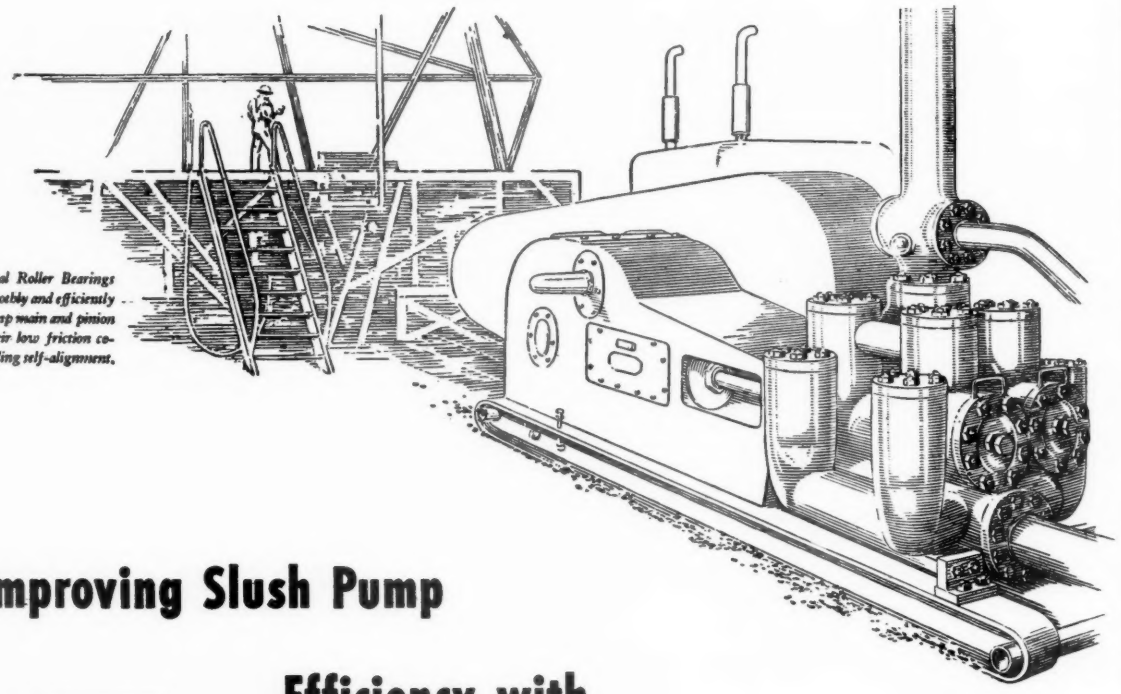

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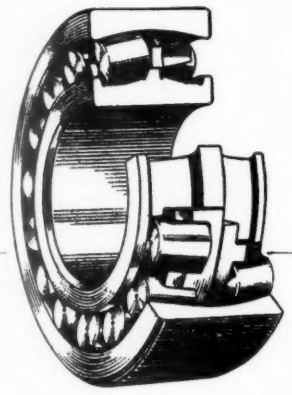

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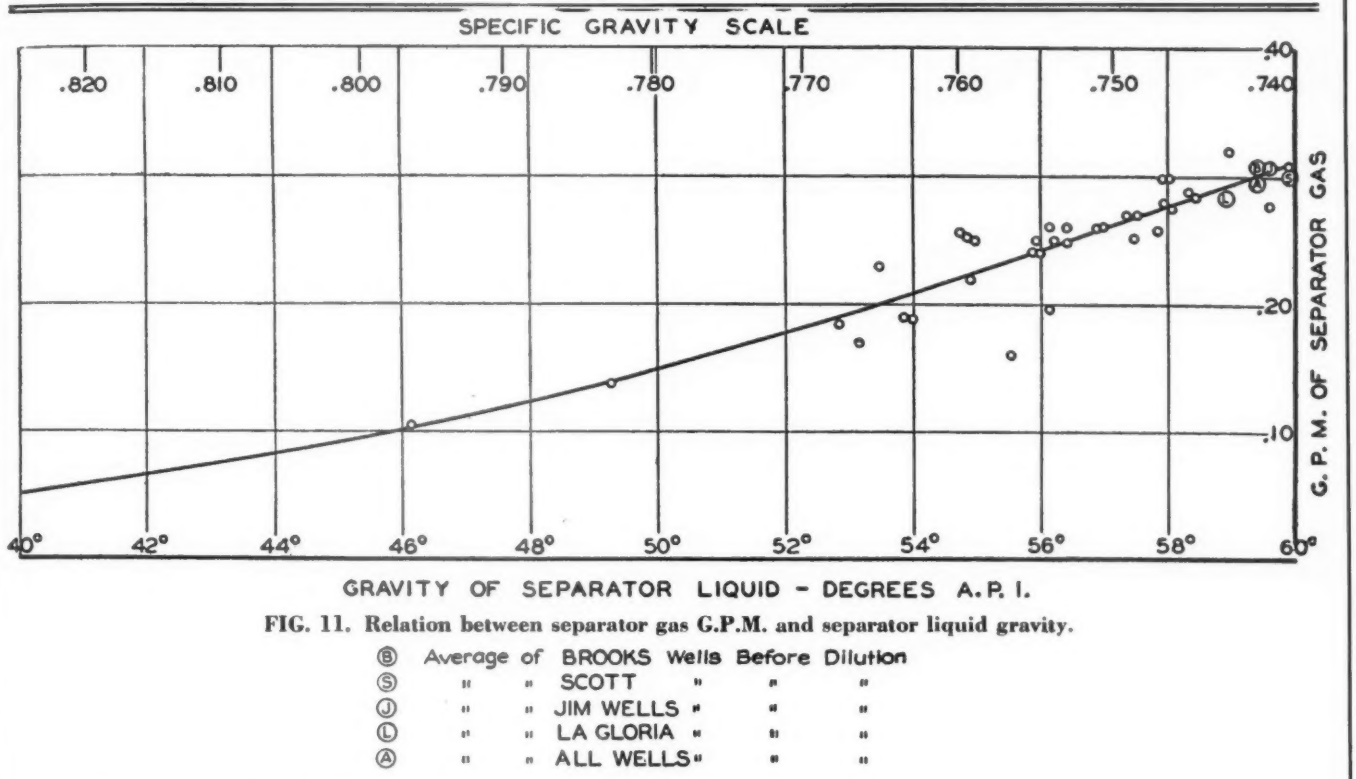

FIG. 11. Relation between separator gas G.P.M. and separator liquid gravity.

Ⓑ Average of BROOKS Wells Before Dilution
Ⓢ " " SCOTT " " "
Ⓙ " " JIM WELLS " " "
Ⓛ " " LA GLORIA " " "
Ⓐ " " ALL WELLS " " "

Fig. 11 is a plot of the separator gas G.P.M. against the gravity of the separator liquid, each point representing a test on a well in the La Gloria field. The data indicate a general trend relationship between the two factors and data from the Stratton-Agua Dulce field show a similar trend. As soon as there are sufficient data to construct such a curve for a field, the curve can be used to check the test data for erraticism and to make closer estimates of dilution.

The reduction in the specific gravity of the gas as it is produced at the well or as it is recovered from the test separator could be used as an indicator, but as the gravity of the injected residue gas is subject to changing plant extraction, this would be a reliable indicator only when the plant extractions had not been changed to an important degree. During the war years, most plants increased butane extraction, and some plants extracted much of the propane. Complete hydrocarbon analysis would also be subject to changes in plant operations as well as to changing flow rates and to sampling errors, therefore it does not appear to be more efficient than the usual G.P.M. test data for detecting invasion of dry gas.

Fig. 10 (right) is a plot that shows that wells do not change abruptly from all wet to all dry gas.

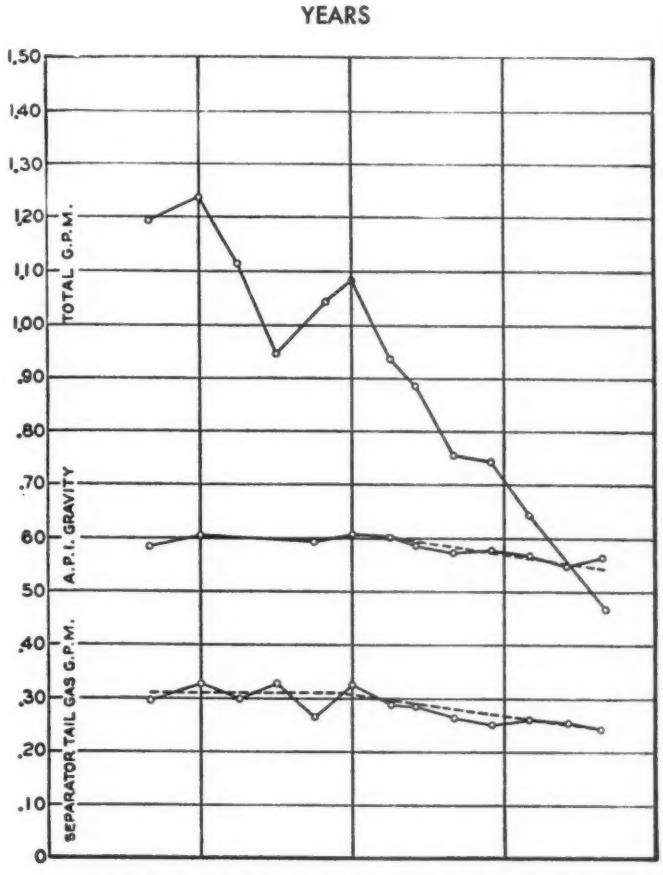

FIG. 10. Plot of G.P.M. record of well invaded by dry gas.

Taken from the article, "Interpretation of Well Test Data in Gas-condensate Fields," by James O. Lewis that was presented before American Institute of Mining and Metallurgical Engineers, Chicago, Illinois, February 1946. Published in *Petroleum Technology*, July, 1946. Published in *The Petroleum Engineer*, September, 1947, pages 180 to 202, inclusive.

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PLATE EFFICIENCY OF FRACTIONATING COLUMNS AND ABSORBERS

This correlation is similar to one presented by Walter and Sherwood who correlated the results on the laboratory column tests reported in Table 2, and is based on the same concepts used in the fractionating column correlation. Actually both correlations (Figs. 1 and 3) could be presented on the same figure, but the difficulty of expressing the solubility effect on the same basis made it more desirable to present two plots.

The average deviation between predicted efficiency in the curve of Fig. 3 and actual efficiency was ± 9 per cent if the points (C) and HP/μ of 0.004 and plate efficiency of 10 per cent and (A) at HP/μ of 0.22 and plate efficiency of 10 per cent are excluded. These were the only two points where the deviation was greater than 20 per cent.

The plate efficiency was plotted against viscosity in Fig. 4. The points scattered widely showing the pronounced effect of material solubility on plate efficiency. The line on the graph is that presented by Drickamer and Bradford for commercial hydrocarbon fractionating columns and absorbers.

● **Effect of tray design and reflux ratio on plate efficiency.** The results of this study show that, with present design methods, the variance in column design found in commercial columns does not affect plate efficiency appreciably. This does not imply that improvement in column design cannot be realized, but on the contrary, shows that in some cases present design methods are not adequate to realize the full potentialities of the concept of a theoretical plate. Therefore, a study of tray design should be made with the purpose of obtaining a design that will overcome the deleterious effect of high viscosity and high relative volatility on plate efficiency.

The correlations presented in this memorandum do not show any effect of reflux ratio on plate efficiency and this is to be expected if the column is operated at the optimum vapor and liquid loads; however, Gerster, Koffolt, and Withrow[9] showed that the relationship $(PTU)_{ov}$, number of actual plates equivalent to a transfer unit, is a function of the reflux ratio as well as the slope of the equilibrium curve. When the number of transfer units equals the number of theoretical plates, $(PTU)_{ov}$ is the inverse of the plate efficiency. This is a special condition that is not always met.

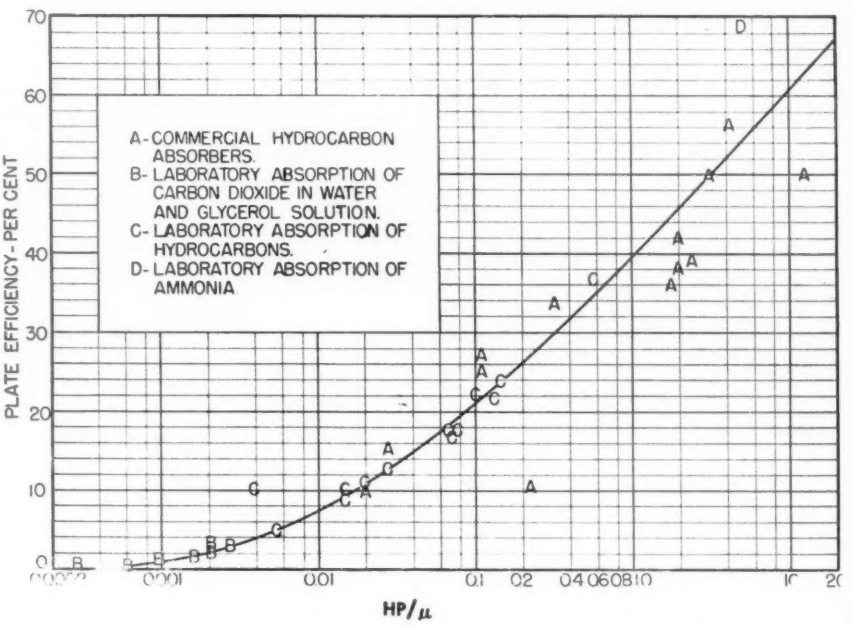
A- COMMERCIAL HYDROCARBON ABSORBERS.
B- LABORATORY ABSORPTION OF CARBON DIOXIDE IN WATER AND GLYCEROL SOLUTION.
C- LABORATORY ABSORPTION OF HYDROCARBONS.
D- LABORATORY ABSORPTION OF AMMONIA
PLATE EFFICIENCY-PER CENT
HP/μ

FIG. 3. Effect of solubility and viscosity on plate efficiency of plate absorbers.

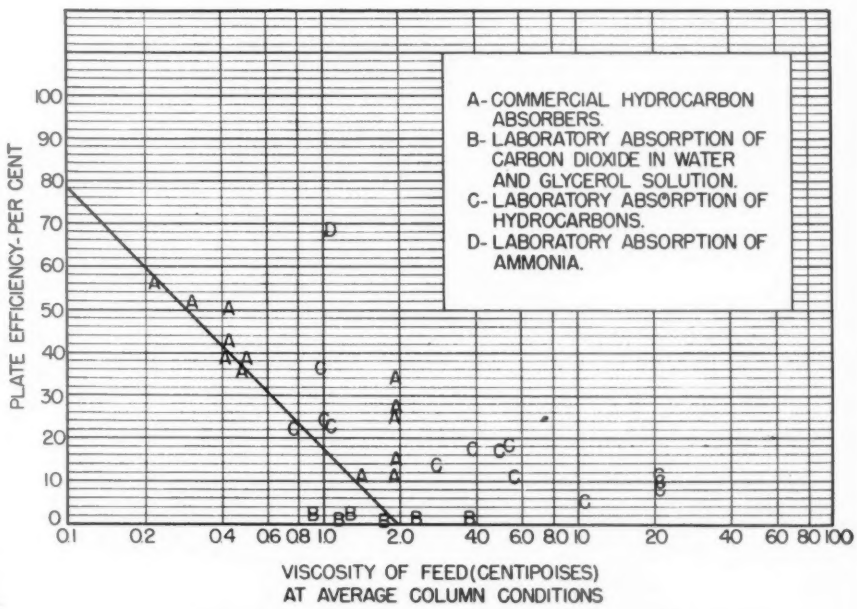
A- COMMERCIAL HYDROCARBON ABSORBERS.
B- LABORATORY ABSORPTION OF CARBON DIOXIDE IN WATER AND GLYCEROL SOLUTION.
C- LABORATORY ABSORPTION OF HYDROCARBONS.
D- LABORATORY ABSORPTION OF AMMONIA.
PLATE EFFICIENCY-PER CENT
VISCOSITY OF FEED(CENTIPOISES) AT AVERAGE COLUMN CONDITIONS

FIG. 4. Effect of viscosity on plate efficiency of plate absorbers.

● **Summary.** Correlations have been presented for predicting overall plate efficiencies of commercial fractionating columns and absorbers within the accuracy of the other variables in design (tray design, physical-property data, and method of calculation). The correlations are semi-empirical and therefore have all the limitations of empirical relationship and should be used as such. A wide diversity of systems was used. For the fractionation column, correlation data were available on hydrocarbon, chlorinated hydrocarbon, alcohol-water and trichloroethylene-toluene-water systems. For the absorber correlation, data were available on the laboratory desorption of carbon dioxide from water and glycerol solution, the absorption of ammonia in water and the absorption of hydrocarbons in oil in both commercial and laboratory columns. Overall plate efficiencies (as defined above) were used although in some cases it was necessary to derive the overall plate efficiencies from Murphree plate and point efficiencies. This latter point should not be considered a limitation of the correlation because such data could be omitted from the correlations without an appreciable impairment of their value.

First published in the August, 1946, Transactions of the American Institute of Chemical Engineers and reprinted by permission of the publishers in *The Petroleum Engineer*, Reference Annual, 1947, pages 200 to 210 inclusive. H. E. O'Connell, Ethyl Corporation, is the author. References will be found on the last sheet in this series.

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INTERPRETATION OF WELL TEST DATA IN GAS-CONDENSATE FIELDS

Fig. 12 shows the record of a well close to the injection well whereas Figs. 9 and 10 shows records of more remote wells. The increases in dilution in these three wells are shown as straight lines against time, but the electrical model and theory both indicate that the relationship will become curvilinear.

This is shown in the hypothetical graph Fig. 13, which illustrates a method for estimating the quantities of dry gas that must be produced from a well, the separator gas G.P.M. being taken as the measure of dilution. The percentage dilution finally reached and the total percentage of residue gas that will be recycled through the sand will depend mostly on economic factors. Operators in the Gulf Coast area generally consider that it is uneconomical to cycle gas with less than 0.3 G.P.M. If by the time dilution starts, the content had dropped to 0.6 G.P.M., production of the well would cease at about 50 per cent dilution, but if the content were 3.0 G.P.M., 90 per cent diluted gas could be processed and reinjected. From Fig. 13 it can be estimated that the 0.6 G.P.M. well would recycle a total of about 10 per cent residue gas and the 3.0 G.P.M. well would recycle about 50 per cent residue gas before the economic limits were reached; that is 10 to 50 per cent of the gas would have to be passed through the sand twice to reach 0.3 G.P.M.

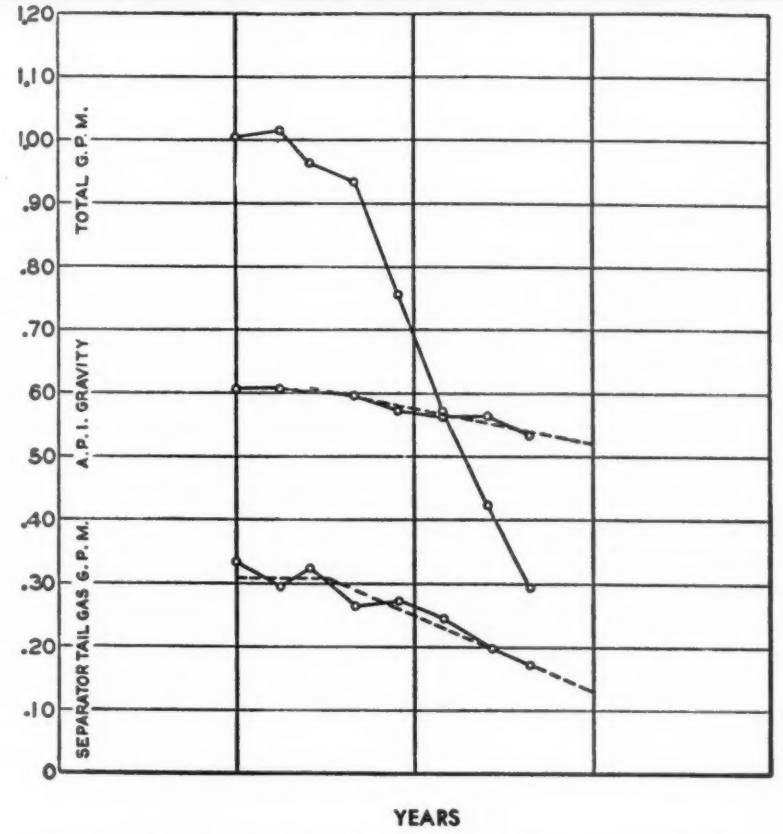
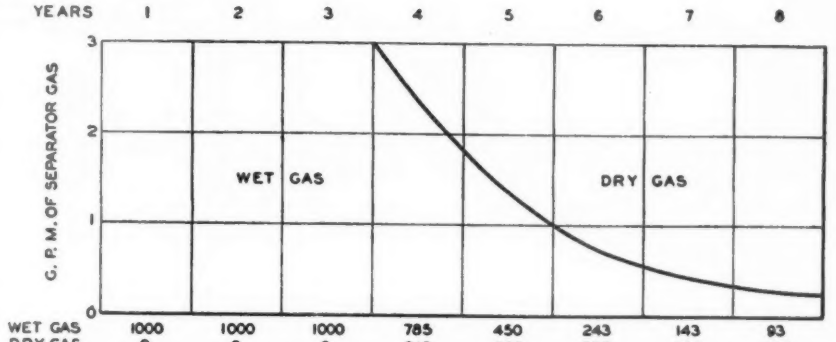


FIG. 12. Plot of G.P.M. record of invaded well near injection wells.



WET GAS	1000	1000	1000	785	450	243	143	93
DRY GAS	0	0	0	215	550	757	857	907
CUM. WET GAS	1000	2000	3000	3785	4235	4478	4621	4714
CUM. DRY GAS	0	0	0	215	765	1522	2379	3286
CUM. TOTAL	1000	2000	3000	4000	5000	6000	7000	8000
CUM. RATIO	100	100	100	105.7	118.1	134.0	151.4	169.5

$$\text{CUM. RATIO} = \frac{\text{CUMULATIVE TOTAL GAS PRODUCED}}{\text{CUMULATIVE WET GAS PRODUCED}}$$

FIG. 13. Chart illustrating method for estimating dry gas to be recycled.

● **Revaporization of condensates.** The revaporization of liquids that had been condensed and retained in the reservoir can occur either by contact with injected dry gas, usually in the retrograde region, or by normal vaporization at pressures below the retrograde pressure. It has been shown that the condensates deposited in the reservoir by retrograde condensation will consist largely of the heaviest hydrocarbons with hydrocarbon gases in solution. The lighter hydrocarbons can be expected to be volatilized readily in either region, but not much of the heavier components can be expected to be vaporized in the normal region.

The dry gas can be expected to revaporize selectively the more volatile hydrocarbons, therefore the first dry gas to reach the well should carry comparatively light hydrocarbon vapors, but they should become increasingly heavy with time, and this in part causes the progressive reductions in API gravity of the pentanes plus shown in Figs. 9 to 12. In the La Gloria field, the heaviest hydrocarbons in appreciable quantities in the undiluted effluent is a liquid of 36.2 deg API, or 0.8436 sp gr with an initial boiling point of 463 F and evaporation point of 647 F. Extrapolation of the trend relationship between separator gas G.P.M. and gravity of separator liquid shown in Fig. 11 indicates that the separator liquid would reach this gravity at 0.05 G.P.M., which indicates a dilution of approximately 0.83⅓ per cent. Fig. 11 can be used as a basis for calculating the approximate gravity of the revaporized liquids contained in the effluent at any stage of dilution.

As revaporization in the retrograde region is so much more effective than in the normal region, it cannot be expected that there will be important normal revaporization in any part of the reservoir that has been swept by dry gas, but there can be expected some recovery of solution gas and of pocketed wet gas when pressures are finally reduced below the retrograde point.

Taken from the article, "Interpretation of Well Test Data in Gas-condensate Fields," by James O. Lewis that was presented before American Institute of Mining and Metallurgical Engineers, Chicago, Illinois, February 1946. Published in *Petroleum Technology*, July, 1946. Published in *The Petroleum Engineer*, September, 1947, pages 180 to 202, inclusive.

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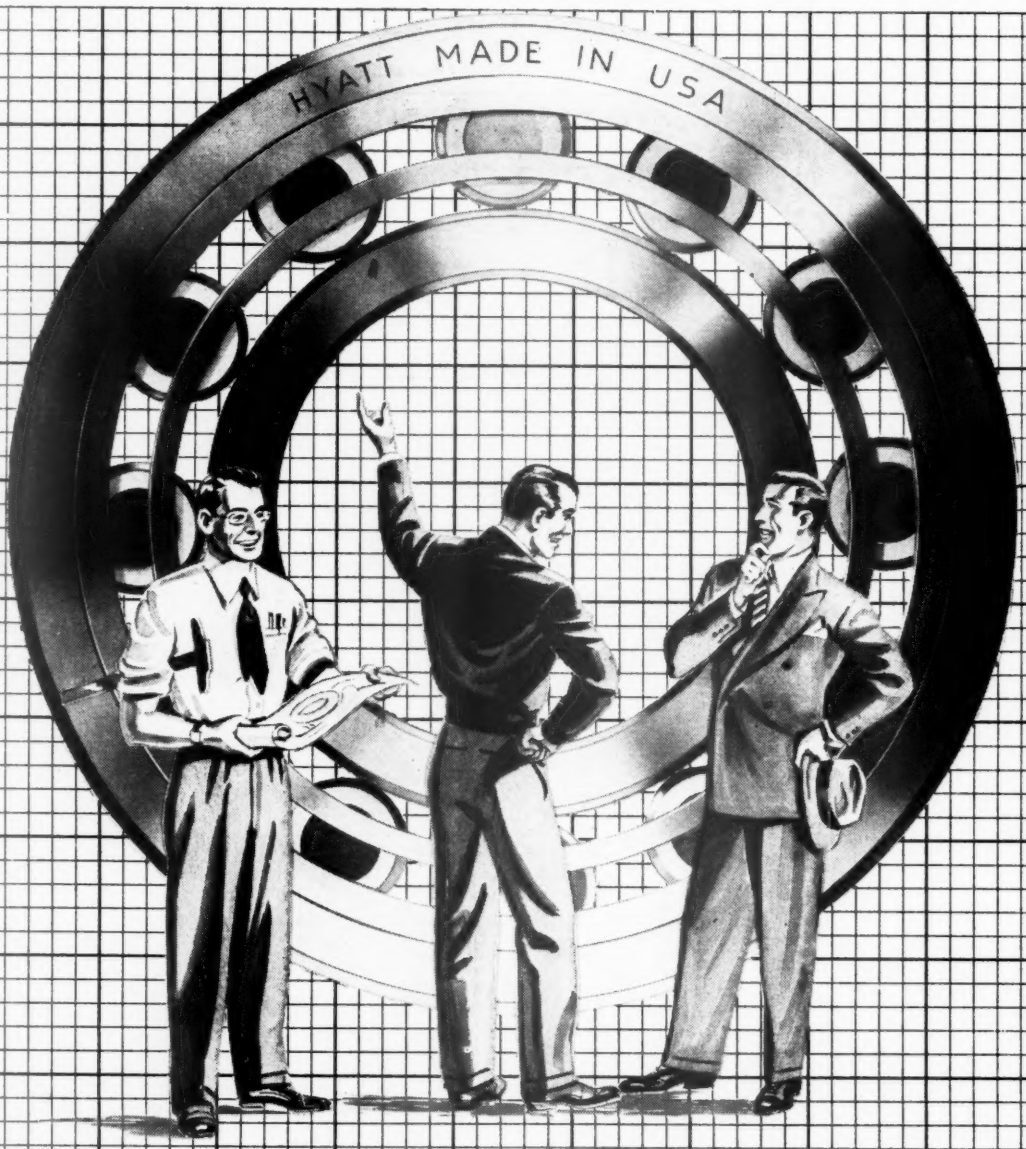

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Relation of water to drilling mud

By E. C. PAGE*

EXCLUSIVE

Most operators today will find it easy to remember a time when rotary mud, its character and constitution, were relatively unimportant matters to the drilling department. When the location stake had been driven for the drilling of a wildcat well, a search of the neighborhood was made for a clay bank, and when it was found only a very cursory examination was made to determine its suitability for drilling purposes. Wells were comparatively shallow, viewed in the light of the deep drilling programs of the present time, and no chemical treatment of mud was considered necessary. As the search for oil broadened, well depths increased proportionately until now engineers and field men generally are fully agreed that the conditioning of drilling mud is one of the most important requisites of the modern drilling process.

During a recent trip to the Mid-Continent and Texas fields, the writer met with many petroleum engineers and field technicians, and discussed the deeper drilling trend and its effect on methods and equipment. It was commonly reported that designs and specifications of heavy drilling machines and appurtenances for wells as deep as 20,000 ft had already been placed in the hands of the manufacturers, but there was a question in the minds of many as to whether techniques could be evolved for the satisfactory handling of other contingencies that might be expected at these increased depths. For example, bottom hole temperatures higher than 400 F are certain to be encountered, as well as pressures far beyond anything so far experienced in drilling operations.

It is obvious that methods must be found to deal adequately with the composition and physical properties of the drilling fluid; to assure its proper chemical treatment, and to see that in all respects it is capable of performing its various functions under more than ordinarily severe conditions, if operators are to accept the risk involved in drilling to the greater depths that are in prospect, that is, with any degree of confidence. Fortunately these things are being done. There is ample evidence to indicate that drilling muds are now the subject of intense research in many parts of the world, and there is reason to hope for worthwhile progress in the better understanding of their constitutional and functional requirements.

Some idea of the interest that is prevalent on this topic may be gathered from the fact that our organization recently published a small booklet on improved methods of conditioning mud, for which requests were received from widely scattered areas. They came from chemists, engineers, and technical personnel representing almost every oil producing area in the world and from some countries in which little or no oil development has yet taken place.

In view of all this interest and the great effort that is being expended in the various fields toward the improvement of materials and techniques, one may look confidently for results. It is uncertain just what changes may be effected to meet the challenge of abnormally high temperatures and pressures. There may be some adaptation of control methods with respect to muds already in use or there may be a radical change to a distinctly new type of drilling fluid. Indeed, there may be discovered some wonder chemical that will answer all the prayers of the driller as adequately as did certain war developed drugs satisfy the needs of the physicians and surgeons.

The introduction of two new drilling muds has already been announced and they are expected to be placed on the market sometime during 1948. Each is reported to be a definite departure from the types of mud now in use. The chemists and engineers of oil companies and service companies are working in close conjunction with field men to bring the application of muds and mud controls to the peak of efficiency. No chemical manufacturer has announced as yet any types of chemical for the treating of mud, but such an announcement may occur at any time. The purpose of this article, however, is not to discuss the merits of any particular type of drilling mud or chemical for the treatment of mud, but to emphasize an aspect of the problem that under commonly existing conditions is frequently highly important in the successful completion of a well.

Innumerable experiments have convinced us that in the proper conditioning of mud for drilling purposes the chemical content of the water is an extremely pertinent factor. This applies not only to the water used directly in the mixing of the mud but also to any formation water with which the mud may be contaminated. Experiments have been carried on in the laboratory and in the field over a period of three years, and they have established beyond doubt that the viscosity, stability, and other properties by which the efficacy of mud may be measured are markedly affected by the concentration in the water of such salts as calcium and magnesium sulphate, and by the hydrogen ion content.

Many operators are today paying as little attention to the water supply as

*Page Laboratories, Ventura, California.

their predecessors of a few decades ago paid to the quality of the mud they took from their local clay banks. The water for drilling purposes, because of necessity, is often obtained from a creek, river, or well, without regard to its chemical characteristics. Yet, as has been indicated, such waters may contain, and usually do, ions such as calcium, chloride, sulphate, and bicarbonate, which in sufficient quantity have a harmful effect when they come in contact with the clay particles in the mud stream.

The following test data is illustrative of the effect upon a mud sample when it comes in contact with even a small percentage of water containing high concentrations of the ions mentioned above. The analysis of the formation water used in making this test is shown in the accompanying tabulation. An analysis of the field water used in making up the mud samples is also shown below. Mud sample No. 1 was made up using the untreated field water. Mud sample No. 2 was made up with the same as used in No. 1 after the water had been conditioned by a method of conditioning used in our laboratory. The two mud samples were then tested before the addition of any formation water to either sample. Two per cent by volume of the formation water was then added to each mud sample, after which the mud was again tested. This procedure was repeated until a total of 6 per cent by volume of formation water had been added to each mud sample.

The water treating agent used in the foregoing tests is a product developed in our own laboratories* and designed specifically for the conditioning of industrial water. It has been used satisfactorily in the treatment of water for mud make-up in many California projects, some as deep as 14,000 ft, and it has been found highly effective in maintaining the stability of the mud, with regard to viscosity, gel strength, weight, cake thickness, and water loss. It was

*Solite.

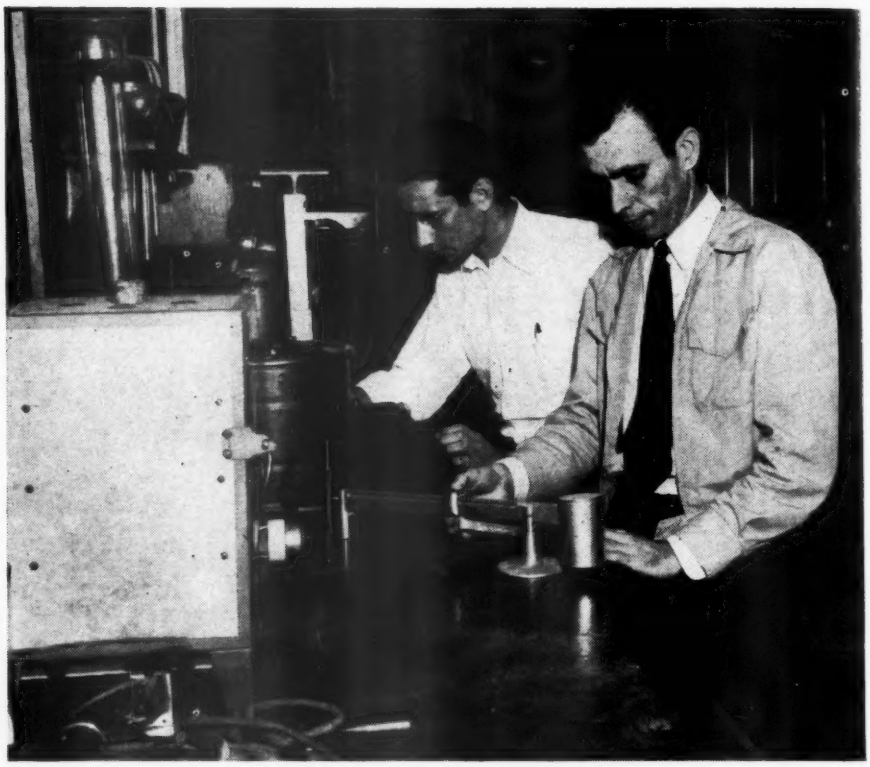
Analysis of field water used in making up the mud samples.

	Parts per million
Calcium as $CaCO_3$	26
Magnesium as $CaCO_3$	84
Sulphate as SO_4	290
Chloride as Cl	284
Carbonate as CO_3	18
Bicarbonate as HCO_3	110
Sodium as Na (Calc.)	327
Total hardness	110

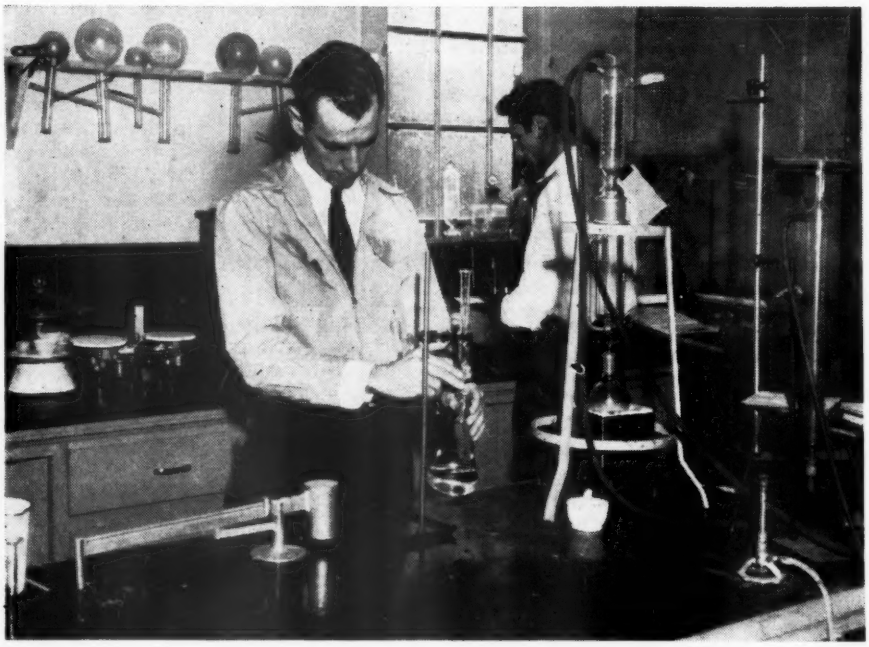
Analysis of formation water added to each sample.

	Parts per million
Calcium as $CaCO_3$	2100
Magnesium as $CaCO_3$	1900
Sulphate as SO_4	46
Chloride as Cl	27304
Carbonate as CO_3	0
Bicarbonate as HCO_3	3355
Sodium as Na (Calc.)	17135
Total hardness	4000

	Mud sample mixed with raw field water	Mud sample mixed with treated field water
Viscosity (500 cc in, 500 cc out)	41 sec.	41 sec.
Shear in lb/100 sq ft (initial)	0 lb	0 lb
Shear in lb/100 sq ft (10 min)	4.5 lb	5 lb
Water loss (60 sec, 100 lb/sq in)	13 ccs.	10 ccs.
Cake thickness, in.	3/32 in.	2/32 in.
Two per cent volume of formation water added; following results obtained:		
Viscosity (500 cc in, 500 cc out)	70 sec.	48 sec.
Shear in lb/100 sq ft (initial)	0 lb	0 lb
Shear in lb/100 sq ft (10 min)	7.5 lb	7.5 lb
Water loss (60 sec, 100 lb/sq in.)	14 ccs	10 ccs
Cake thickness, in.	3/32 in.	2/32 in.
Another 2 per cent by volume of formation water added; following results obtained:		
Viscosity (500 cc in, 500 cc out)	Over 2 min.	68 sec.
Shear in lb/100 sq ft (initial)	10 lb.	3 lb.
Shear in lb/100 sq ft (10 min)	30 lb.	9 lb.
Water loss (60 sec, 100 lb/sq in.)	15 ccs	11 ccs
Cake thickness, in.	4/32 in.	3/32 in.
Then 2 per cent more by volume of formation water added; following results obtained:		
Viscosity (500 cc in, 500 cc out)	Too high to measure	2 min.
Shear in lb/100 sq ft (initial)	15 lb	4.5 lb.
Shear in lb/100 sq ft (10 min)	50 lb	15 lb
Water loss (60 sec, 100 lb/sq in.)	16 ccs	11 ccs
Cake thickness, in.	3/32 in.	3/32 in.



An important factor in mud analysis is the weight per cu ft. It is determined by means of mud balance, here being manipulated in the foreground by a chemist, J. M. Smith. In the background is J. R. Bruce, also of Page Laboratories in analytical work. Below Smith performs a titration in a water analysis. With W. A. Simpson, he developed the tabulations at left, which indicate that drilling mud, water loss, etc., may be controlled by treated makeup water.

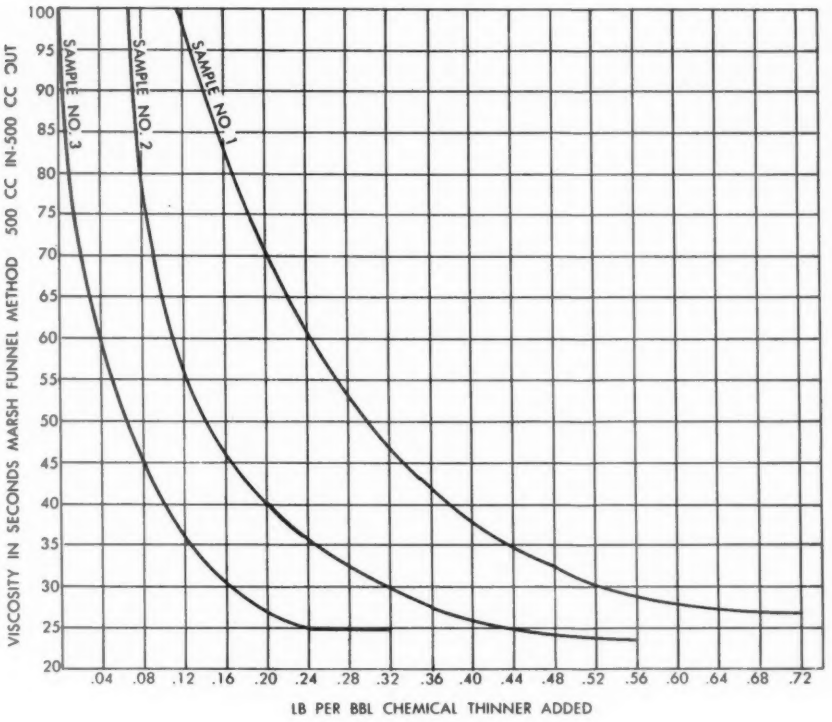


developed after careful weighing of all the facts and factors, and the examination of many mud samples with regard to the effect of certain calcium and magnesium salts and other contaminants, most of which were present in the mud make-up water.

It will be noted in the tabulation that the water loss on the mud samples mixed with treated water was 3 ccs, less than that mixed with the raw field water. Then as the first increment of formation water was added the water loss on the treated sample remained the same (10 ccs), whereas that of the raw water sample increased from 13 ccs to 14ccs, and the viscosity of the untreated sample increased 29 seconds as against only 7 seconds for the treated sample.

When the second and third increments of formation water were added, the sample mixed with treated field water showed a water loss of 11 ccs, and the untreated sample increased to 16 ccs. The viscosity of the untreated sample rose beyond measurable limits, whereas that of the sample mixed with treated water was much less. Also, the sample made with treated water retarded the increase in gel strength, the final reading being 15 lb against 50 lb for the sample mixed with raw water.

A further comparison of the effects of treated water muds and raw water muds in drilling operations is to be found in the accompanying viscosity chart. The curves as shown represent the effect of treated water and raw water on the action of a commercial mud thinner in reducing the viscosity of mud. The samples represented by the three curves contain equal portions of clay and gel. The clay and gel are the same commercial brands in each sample. The water used in preparing Sample No. 1 was raw field water. The water used in preparing Sample No. 2 was the same as that used in Sample No. 1 except that it was treated with ¼ lb of compound per bbl of water. Sample No. 3 was treated with ½ lb of compound per bbl of water.



Curves show effect of properly treated water as compared with raw water upon the action of a commercial mud thinner in reducing viscosity of mud. Samples represented by the three curves contain equal proportions of the same clay and gel with raw or treated water.

From the chart it may be seen that mud samples prepared with treated water responded more rapidly and consequently more economically to treatment. The viscosity decreased more rapidly and reached a minimum with the addition of less chemical thinner. On successive tests with these same mud samples, the treated samples retained the effect of the treatment for a longer period than the samples prepared with raw water, which showed an early tendency to lose the effect of the treatment. It is thus evident that the treated water imparts a quality of stability to drilling mud, an effect that is eminently desirable, and that, it might be mentioned, has been corroborated in a number of actual field mudding operations.

It is at once conceded that water treatment is not a panacea for all the ails and problems of the mud engineer. On the other hand, there is no question that proper treatment of make-up water will tend to lessen the chance for the occurrence of many common mud difficulties. In the treatment of the water for make-up it would seem that a potential trouble maker is eliminated at the source. As a general rule, the facilities available at the well are quite adequate to permit water treatment for drilling mud purposes right on the spot.

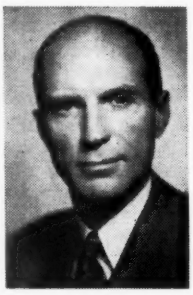
Different operators occasionally employ novel tank hook-ups to fit some particular local requirement. In the main, however, all that is needed is a setting of two tanks, each equipped with a bottom drain cock to draw off the precipitate that is formed during water treatment. With such a setup, one tank can be settling while treatment goes on in the other; however, very good results have been obtained where only one tank is used for water treatment. The settled out precipitate should not be used in the mud stream. Sometimes an operator will use the water drained from the tank bottom for washing the floor of the rig and the machinery, a practice that saves water where the supply is limited.

It is necessary, of course, to have a laboratory analysis of the raw water to determine the required amount of treatment, and it is to be noted that an over treatment may very easily prove much less effective than one that is properly gauged. By the same token, it might be emphasized that data gathered in laboratory experiments, and pointing the advantages of treating make-up water for drilling muds, are fully confirmed by actual field experience. Treatment of mud make-up water in many wells, a fair percentage of which were having trouble of one sort or another before changing to treated water, produced results even beyond expectation. Certainly they appear to indicate that the precaution herein described, although low in cost, is a pertinent factor in effective and efficient mud control. ★ ★ ★

The treating agent may be just dumped into the water tank, or, as in this case, brought into the fluid quickly by an air stream. The precipitate formed settles quickly, and may be drawn off through a bottom bleed line.

running tour with men in the industry

● **Howard B. Nichols,** vice president in charge of refining of the Bahrein Petroleum Company, Ltd., has been elected assistant vice president in charge of refining of the California Texas Oil Company, Ltd. Bahrein and the California Texas are both Standard Oil Company of California affiliates.



H. B. Nichols

Nichols joined Standard of California in 1923, soon after his graduation from Stanford University with a degree in engineering. After a year in the general engineering department he transferred to the research and development department, which has since become a part of the California Research Corporation.

During the early thirties Nichols specialized in cracking processes, and for seven years was in charge of all plant and laboratory research and development work on cracking and related refining processes. He assisted in the design of the Bahrein Refinery, which began construction in 1936, and became manager of research and development of the Bahrein Petroleum Company, Ltd., in January, 1938. He was named assistant vice president of the Bahrein firm in 1944, and became vice president of it this year.

● **H. E. Amox** has been transferred to the McAllen, Texas, store as manager, by The Continental Supply Company, Dallas. Amox has been serving at the Alice, Texas, store as warehouseman. He succeeds **W. O. Bright,** who has been appointed field salesman at McAllen.

● **Afton D. Puckett,** widely known in the petroleum industry for his work in anti-knock properties of motor fuels for the government, has joined the Du Pont Company's Petroleum Chemicals Division. Puckett has been put in charge of operations of all anti-knock equipment in connection with Du Pont's entry into the direct marketing of tetraethyl lead compounds. He will be stationed at the engineering laboratory at Deepwater Point, New Jersey.

A. D. Puckett

Since graduation from Oklahoma A. & M. College in 1936, with a B. S. degree in chemical engineering, he has been associated successively with the Tide Water Associated Oil Company, the National Bureau of Standards, and the Bureau of Mines Petroleum Experiment Station.

● **Robert L. Gibson** has been named manager of a newly created personnel division of the General Electric chemical department, which has responsibility for matters pertaining to employe relations, union relations, community relations, and educational activities in the various divisions and plants of the department. Dr. Zay Jeffries, vice president of the company and general manager of the chemical department, who made the announcement, said that Gibson will continue as manager of the advertising and sales promotion division.

Assisting Gibson will be **Everett W. Bickford** as manager of union relations, **George M. Hartley** as supervisor of planning and preparation, **Karl B. McEachron, Jr.,** as manager of educational activities, and **Arthur G. Sanford** as manager of personnel services and safety.

● **William Carl Clemons** retired February 1 as superintendent of production for Gulf Oil Corporation, Gulf Refining Company, Houston district, after more than 44 years in the business. As a boy Clemons caught one of the excursion trains to Beaumont to see for himself the fabulous Lucas gusher at Spindletop. Instead of returning to the farm home of his parents in Ellis County, Texas, he got a job on an oil rig as driller. As a driller, assistant superintendent of production, and more recently as superintendent of production for Gulf in the Gulf Coast, he has taken a personal interest in practically every well drilled by Gulf in this area during the last 40 years.

W. C. Clemons

● **Theodore C. Coleman,** formerly an official of the Northrop Aircraft, Inc., has been appointed assistant treasurer of the Standard Oil Company of California.

● **John C. Millar,** for many years prominently identified with the petroleum industry, died in Buffalo on January 3. Millar joined The British American Oil Company Limited in 1919 as office manager and subsequently rose to the position of treasurer in 1927. He was elected a director of the company in March, 1935, and held this position until early last year when he retired due to ill health.

In addition to his duties as financial officer of the parent company, The British American Oil Company, Ltd., Millar, for many years, was vice president of The British American Oil Producing Company at Tulsa, Oklahoma, and through this association was widely known in the United States.

● **Bernard "Barney" E. Horrigan,** retired oil man, died in Tulsa, Oklahoma, January 10 after an extended illness. Born in Corry, Pennsylvania, on June 9, 1876, he moved to Tulsa in 1906. Starting as a pumper in the Pennsylvania and Ohio oil fields, he worked his way into an executive position.

B. E. Horrigan

Known throughout the industry for his wit and humor, he was the originator of "Laugh With Barney," humor page of *The Petroleum Engineer.*

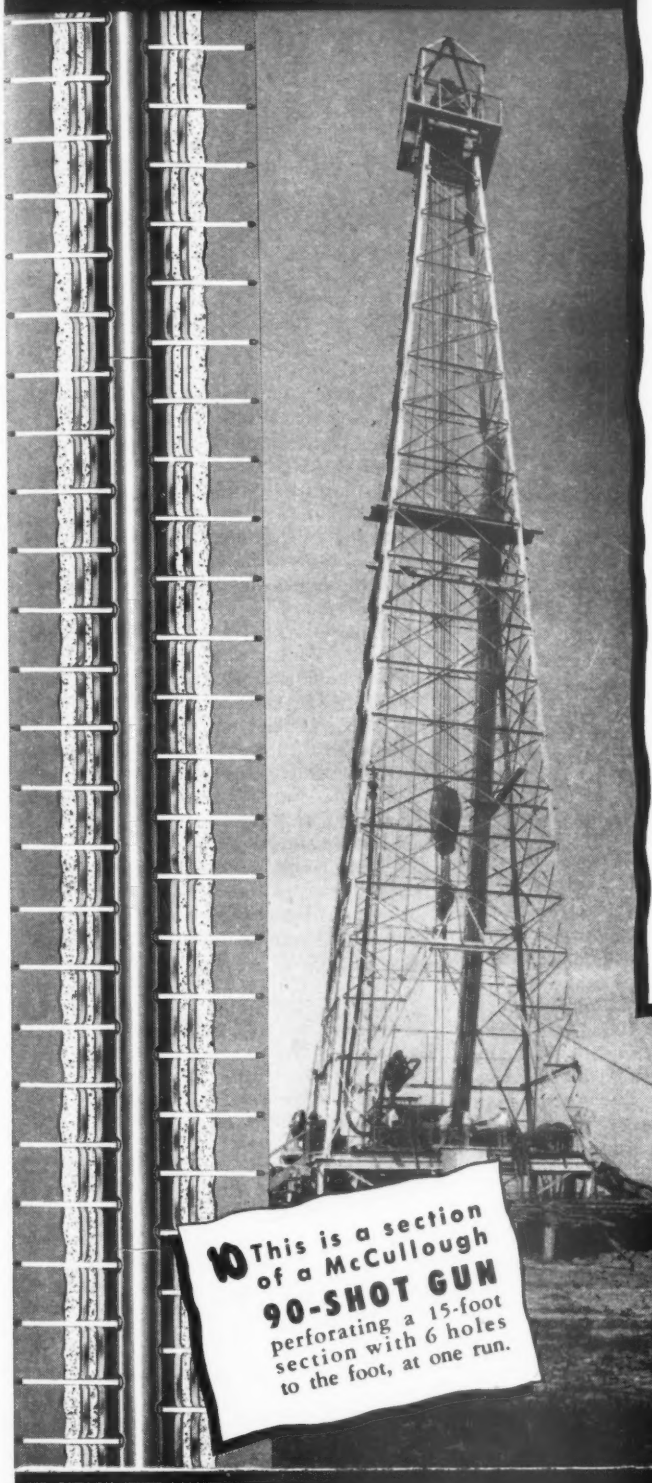
● **Andrew Neilson** has been made president of Overseas Tankship Corporation, an affiliate of Caltex. Neilson, who has sailed as an officer on American ships, and holds a master's license, as well as a degree from Stanford University, has been directly connected with shipping activities for the last 25 years. Most of this time has been spent with affiliates of Overseas Tankship, either afloat or ashore, particularly as general manager of Pacific Tankers, Inc., San Francisco, California. He joined Overseas Tankship Corporation as vice president and general manager in June, 1946.

● **A. W. MacMurtrie,** refinery manager, has announced the promotion of eight Marcus Hook employes of Sun Oil Company to new positions.

William J. Devonshire, Jr., is named general foreman at 16 Plant; **Robert F. Gourley,** supervisory foreman at 16 Plant; **John L. Quillen, Sr.,** foreman of Solvent Refining Section; **John C. Bullock,** assistant foreman, Solvent Refining Section, and **Walter S. Buckley, Jr., Herbert A. Stringfellow, Herman McFadden,** and **John R. Rue III** assistant foremen at 16 Plant.

● **Dr. Paul H. Giddens,** Meadville, Pennsylvania, Allegheny College professor and a noted authority on the history of the petroleum industry, has been granted a two-year leave from teaching duties to write a complete history of the Standard Oil Company of Indiana. Dr. Giddens, who is the author of four books and many articles on the oil industry, is recognized as one of the country's outstanding authorities on the history of petroleum. In 1945 he was awarded a Guggenheim Fellowship to write a volume on "The Growth of the Petroleum Industry, 1870-1895." His other books include "The Birth of the Oil Industry," 1934; "The Beginnings of the Petroleum Industry: Sources and Bibliography," 1941, and "Pennsylvania Petroleum 1750-1872: A Documentary History," 1947. Since 1943 he has been curator of Drake Museum, Titusville, Pennsylvania.

10 GOOD REASONS WHY OPERATORS PREFER



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1. **MEETS EVERY CONDITION.** Guns fired either electrically or mechanically: guns run on cable, sand line, drill pipe, tubing, or on piano-wire measuring line in extremely high-pressure wells.
2. **SIMULTANEOUS FIRING** under all conditions gives exact spacing of shots, perfect perforation pattern, and saves down-the-hole time.
3. **ACCURATE DEPTH MEASUREMENTS** put the shots right where you order them.
4. **MAXIMUM PENETRATION** of bullets into the formation, as proved repeatedly in competitive field tests.
5. **GUNS TO FIT EVERY CONDITION.** McCullough employs more than 30 different types and sizes of guns.
6. **ALL SIZES OF BULLETS** from $\frac{1}{16}$" dia. up to $\frac{3}{4}$" dia., to fit every possible need.
7. **BURRLESS BULLETS,** giving a completely burr-free hole, eliminating casing scraping, with *no* sacrifice of penetration.
8. **NO LOST TIME.** McCullough's simpler, lighter equipment cuts setting-up and moving-out time, speeds up every job.
9. **EXPERIENCED MEN.** With years of experience behind them, thoroughly-trained McCullough gun-perforating crews do their jobs quickly, efficiently, safely.

These Are Some of the Reasons Behind the Proven Fact That

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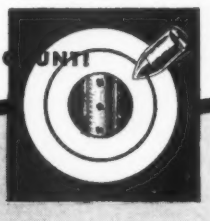

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Corpus Christi	Oklahoma City	Hobbs	Bakersfield	New Iberia
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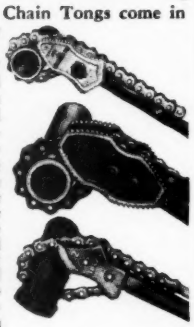

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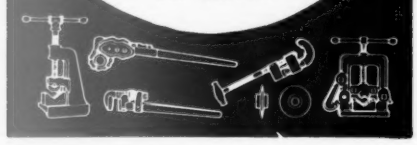

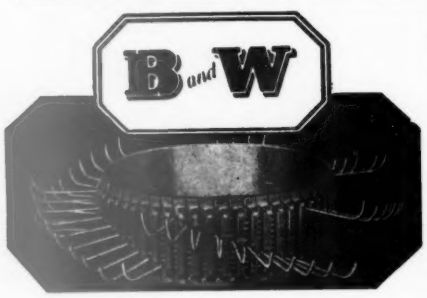

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● **Richard (Dick) R. White,** service engineer for Oil Base, Inc., Compton, California, manufacturers of Black Magic oil base drilling fluids, has been transferred from the Los Angeles Basin area to the Houston area. White, a former Texan, will have an opportunity to renew old acquaintances. He will make his headquarters at the Oil Base, Inc., Houston office in the Southern Standards Building.

● **E. O. Buck** has become associated with the National Bank of Commerce, Houston, Texas, as manager of its oil loan department. He has had broad experience in geological and production work throughout the Southwest, and especially in the Gulf Coast area. Since 1933 he has made Houston his headquarters.

E. O. Buck

Buck was employed from 1926 until 1931 by Gulf Production Company as geologist. From 1931 to 1933 he was employed as division engineer for Texas Railroad Commission. From 1933 to 1935, he was chairman of the Engineering Committee of the Conroe Operators Association in the Conroe field. In 1935, he opened an office in Houston as consulting geologist and petroleum engineer. From 1941 to 1943, he served as director of production for the Petroleum Administrator for War in District 3. From 1943 to the present time, he has been employed as southern manager for the Rowan Drilling Company in its Houston office.

● **Gage Lund** has been elected to the board of directors of the Standard Oil Company of California. Lund, has been chairman of the board of The California Company and the Standard Oil Company of Texas, both wholly owned subsidiaries of Standard of California. They operate in the Rocky Mountains, Texas, and the Southeast.

Gage Lund

A native of Iowa, Lund studied at Montana State College and Stanford University, graduating from the latter in 1924. He joined Standard the following year and worked as a geologist and drilling foreman in the Rockies and Texas for the next 11 years until he became division superintendent of The California Company's Gulf Coast division, with offices in Houston.

In 1938 he was made assistant manager of all operations of The California Company and Standard of Texas, and three years later was elected president of The California Company. Election to the position of chairman of the board of both companies came in 1945, with headquarters in San Francisco.

● **J. H. Russell,** vice president of Gulf Oil Corporation and Gulf Refining Company, has announced that effective February 1, **E. P. Hubbard** is appointed superintendent of production for the Houston district succeeding **W. C. Clemons,** pioneer Texas oil man who is retiring. **J. M. Cooper,** now chief petroleum engineer of this district, is appointed assistant superintendent of production succeeding Hubbard, and **E. L. Petree** is appointed chief petroleum engineer succeeding Cooper.

E. P. Hubbard

Hubbard has been with Gulf since 1920 and has served continuously as assistant superintendent of production, Houston district, since 1933 except for a temporary assignment as manager of the Kuwait Oil Company, Limited, Kuwait, Persian Gulf, from May 10 to September 23 last year. A native of Lampasas County, Texas, he was graduated from Texas A and M College in 1917 and was an instructor in electrical engineering at A and M for one year following his discharge as a captain of infantry at the close of the first World War.

Cooper started with the Gulf Companies at Hull, Texas, about 25 years ago. Born in Cedar Rapids, Iowa, he attended high school and college in Cedar Rapids, and the Carnegie Institute of Technology in Pittsburgh.

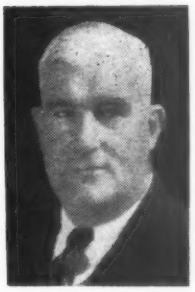
Petree, who is being promoted from assistant chief petroleum engineer to chief petroleum engineer, is a graduate of Texas A and M, class of 1934. Beginning with Gulf in 1935, he worked first in Louisiana, then as an engineer in the East Texas oil field with headquarters in Kilgore.

● **Norman Thompson** has been appointed assistant superintendent in charge of refinery laboratories at Sun Oil Company's Marcus Hook Refinery. Thompson, who moves from the development division to the operating department of the Marcus Hook Refinery, will have charge of all matters having to do with the quality of Sun products including specifications and laboratory control.

At the same time **George S. Rostron** was appointed special assistant to Thompson and **Charles C. Kline** was made operating engineer of a new wax manufacturing plant and new furfural solvent extraction plant.

● **Stuart D. Watson** has been promoted to assistant advertising manager of Standard Oil Company (Indiana). He joined the company in 1939 as advertising clerk in the South Bend, Indiana, sales field, where he was a salesman when inducted into the army as a private in 1943. Upon his discharge as a captain in the infantry in 1946 following service in the Philippines, he returned to Standard of Indiana as executive assistant to the advertising manager in the general office at Chicago.

● **James J. Cosgrove** was elected chairman of the board of directors of Continental Oil Company at a recent meeting of the board in New York City. Cosgrove has been with Continental Oil Company since 1929. He was born in North Braddock, Pennsylvania, received his high school education at Pittsburgh Academy, and is a graduate of Pittsburgh Law School. He was admitted to the bar in 1912, and established a law office in Pittsburgh, where he practiced until 1917 when he entered the army.



J. J. Cosgrove

After the armistice Cosgrove became a member of the War Department board of appraisers, and subsequently a member of the War Department claims board. In 1921 he was appointed special attorney to the commissioner of internal revenue, and in 1922 joined The Texas Company where he acted in a legal capacity until he became general counsel for Continental Oil Company in 1929.

● **Hugo A. Anderson** has been elected a director of Warren Petroleum Corporation, succeeding **J. H. Boyle** who resigned as an officer and director, effective January 1. As vice president of The First National Bank of Chicago, Anderson for the last 20 years has been actively engaged in the financing of production, refining, and distribution in the petroleum industry. He also is a director of The Chicago Corporation and of the Union Asbestos and Rubber Company.

● **K. Marshall Fagin,** Dallas, Texas, field editor of *The Petroleum Engineer*, was the principal speaker at a meeting of the Student Section of the AIME at the University of Texas recently. He gave an interesting talk on his trip to Point Barrow, Alaska, last summer to inspect the government naval oil reserves development in that area. The talk was supplemented with movies in technicolor and colored slides taken both from the air and at various points of interest in the drilling operations.

● **Theodore R. Corbett,** Billings, Montana, has been appointed manager of the manufacturing department of The Carter Oil Company, effective February 1. For the past year and a half he has served as manager of Carter's Northwest Division manufacturing department. Simultaneously, it was announced that headquarters for all Carter manufacturing operations, formerly in Tulsa, will be centered in Billings.

Corbett began his career in the field of petroleum refining in Billings 17 years ago as a chemist for the Yale Oil Corporation's refinery, which was acquired by Carter in 1944.

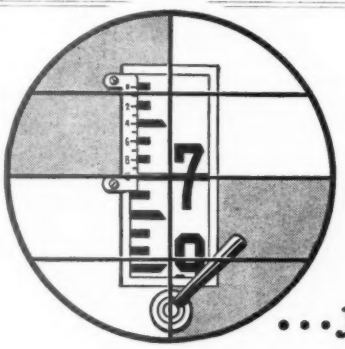
Paul C. Shea, formerly head of Carter's manufacturing organization, goes to New York to be associated with the Esso Standard Oil Company.

● **J. W. Holmes** has been appointed sales manager of the Jefferson Chemical Company, Inc., owned jointly by The Texas Company and American Cyanamid Company. His headquarters are at 30 Rockefeller Plaza, New York, New York. Holmes is in charge of sales of commercial products.

J. W. Holmes

A graduate of McGill University, Holmes for several years handled technical sales of organic chemicals and neoprene for Canadian Industries Limited in Montreal and Toronto. In 1942 he joined the Polymer Corporation at Sarnia, Ontario, as executive assistant to the managing director, and later was placed in charge of technical service for Butyl rubber. In 1945 Holmes became manager of the Polymer Corporation's sales and technical service division.

● **Dr. Robert D. Stiehler** has been appointed chief of the Testing and Specifications Section of the Division of Organic and Fibrous Materials, National Bureau of Standards. Well known for his research on rubber, Dr. Stiehler was instrumental in developing methods of quality control for synthetic rubber production in government plants during the war.



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Illustrated, famous Type II Transit No. 7016. Telescope 11½" long — internal focusing — 24 power. Horizontal limb graduated to 15 minutes, Verniers to 20 seconds, 6½" diam.

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● **K. G. Holdom** has been appointed eastern representative for the Gas Processes Division of The Girdler Corporation, Louisville, Kentucky, it is announced by W. R. Wood, vice president. Holdom is a graduate of the Massachusetts Institute of Technology, and soon after receiving his degree joined the M. W. Kellogg Company. With Kellogg he worked in the process division and also aided in the development of the fluid catalytic cracking and hydroforming processes. During the war he was employed by the Cities Service Refining Corporation at Lake Charles, Louisiana, and later joined the Houdry Process Corporation as a project analysis engineer in the sales department.

K. G. Holdom

The New York offices, where Holdom is stationed, are at 150 Broadway.

● **Harry Green** and **Carl Senn** have been appointed to consulting positions on the staff of The Falk Corporation. Green is consultant on machine shop operations, and Senn is consultant on methods engineering. **B. C. Bugbee,** former production control manager, was appointed machine shop superintendent. In this capacity he directs all machine shop and production control operations.

● **Gaylord L. Barrick** has been appointed head process engineer of the Votator Division of The Girdler Corporation, Louisville, Kentucky. Barrick is a native of Brazil, Indiana. He received his B. S. Ch. E. degree from Rose Polytechnic Institute, and his M. Ch. E. degree from the University of Louisville. He later did postgraduate work at Purdue.

G. L. Barrick

Barrick joined the Votator Division in December, 1943, and was at first associated with pilot plant operations. He joined the process department in January, 1946, and has had an important part in the Votator Division's expansion program.

● **Dr. Gordon M. Kline,** chief of the Organic Plastics Section at the National Bureau of Standards, has been made assistant chief of the Division of Organic and Fibrous Materials.

● **G. Stewart Brown,** former state department official, has been appointed manager of the public relations department of the Standard Oil Company of California. Brown, for many years a foreign correspondent in Europe, has had a wide variety of experience, including service with the American Red Cross as national vice chairman in charge of public relations of the Allied Commission in Italy.

G. S. Brown

Born in Buckeye, Arizona, he was graduated from the University of Arizona in 1927. During his final college year he was a reporter on the *Tucson Daily Star* and after graduation became a member of the staff of the Paris edition of the *New York Herald Tribune*.

Two years later Brown joined the United Press and during the following ten years held a number of increasingly important positions with this organization. In 1939, he resigned from United Press to become director of public information for the American Red Cross in Washington and four years later was appointed vice chairman in charge of national public relations and fund raising for the Red Cross.

Because of his intimate knowledge of Italy, the War Department requested his services in February, 1945, as director of public relations of the Allied Commission in Italy. Brown served in this capacity till September, 1946, when he returned to Washington and was appointed deputy director of the Office of Information and Educational Exchange which position he held until he resigned to become associated with Standard.

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● **Ray Hayes,** diesel sales engineer for Mid-Continent Supply Company, is now working out of the export division in New York. Hayes has been with Mid-Continent Supply Company since 1937, representing the diesel department in Wichita, Kansas, and New Orleans, Louisiana. He served as a captain in the Air Corps during the war. Coming back to the company after the war, he began work at the Fort Worth offices, then went to the Houston office for a while before returning to Fort Worth where he was promoted to sales engineer. He stayed there until his transfer to New York a few months ago.

Ray Hayes

● **William B. Watson** is now associated with David Donoghue, consulting geologist and engineer, of Fort Worth, Texas. Watson, formerly in the production and engineering departments of the Gulf Oil Corporation and captain in the U. S. Marine Corps in the Pacific during World War II, is now completing requirements for the degree of master of science in petroleum engineering at the University of Texas. He is a member of Tau Beta Pi and Sigma Gamma Epsilon, honorary engineering and geological fraternities, and The Ramshorn, engineering scholarship society.

W. B. Watson

● **John S. Ball,** senior refinery engineer in the Petroleum and Oil Shale Experiment Station of the Bureau of Mines, Laramie, Wyoming, has been elected chairman of the Wyoming Section of the American Chemical Society. He succeeds **Prof. Ernest R. Schierz,** head of the chemistry department of the University of Wyoming. Other new officers are: **Dr. Henry G. Fisk,** director of the University's Natural Resources Research Institute, chairman elect; **Dr. J. Thomas Field,** professor of chemistry in the university, secretary, and **L. E. Walter,** state chemist, treasurer. Elected to the Society's National Council was **Dr. F. C. Freytag,** professor of chemistry in the university.

● **W. A. Roberts** and **W. C. Johnson,** executive vice presidents of Allis-Chalmers Manufacturing Company, have been elected to the firm's board of directors. Roberts is executive vice president in charge of the company's tractor division and Johnson is executive vice president for the general machinery division.

The new directors succeed the late Dr. Charles E. Albright and Harold S. Falk, president of the Falk Corporation. Falk had submitted his resignation because of other business requirements.

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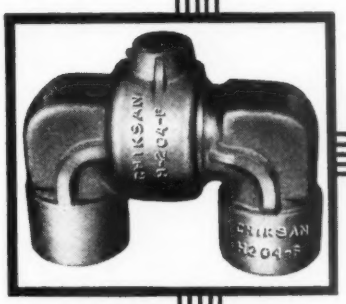
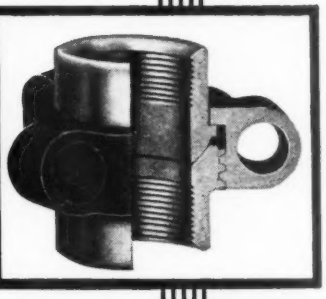
When you fit up swing lines, you want perfect flexibility with low torque, dependable unions and a lubricant that will prevent threads from rusting and freezing. You get all THREE of these advantages with the CHIKSAN-WECO Combination.

CHIKSAN Ball-Bearing Swivel Joints turn on double rows of ball bearings. That means smooth, easy action with low torque. There is nothing to tighten or adjust. That means low maintenance cost. CHIKSAN Packing Units are designed for many different services and pressures. That means dependable service.



CHIKSAN Ball-Bearing SWIVEL JOINTS



WECO WING UNIONS

WECO Wing Unions are made in a wide range of types and sizes for pressures to 12,000 psi. Thoroughly tested and widely accepted by the Petroleum Industry, under the most severe conditions, WECO Wing Unions are now available to users in all lines of industry.

WECO Thread Lubricants provide a perfect seal and complete protection against rust and corrosion. They do not harden under any conditions. Lines are easily set up or dismantled without injury to threads or fittings.

WECO THREAD LUBRICANTS

Representatives in all Principal Cities

WELL EQUIPMENT MFG. CORP. HOUSTON 1, TEXAS
MID-CONTINENT AREA

CHIKSAN EXPORT CO. BREA, CALIFORNIA • NEW YORK 7
EXCLUSIVE EXPORT REPRESENTATIVE

CHIKSAN TRADE MARK
BALL-BEARING SWIVEL JOINTS FOR ALL PURPOSES

CHIKSAN COMPANY
BREA, CALIFORNIA
New York 7 Houston 1

For Your Next Job
STOP and CONSIDER the
FLEXIBILITY
of the
Peerless Vertical Turbine Pump

1. AS A DEEP WELL PUMP

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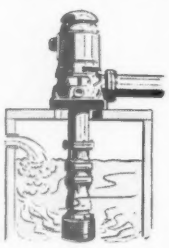

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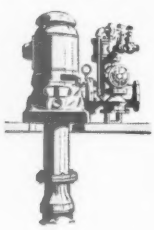

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fmc PEERLESS PUMPS

PEERLESS PUMP DIVISION
Food Machinery Corporation

Factories: Los Angeles 31, Calif.; Quincy, Ill.; Indianapolis, Ind. *District Offices:* Chicago 40, 4554 N. Broadway. Philadelphia Office: Suburban Square, Ardmore, Pennsylvania; Atlanta Office: Rutland Building, Decatur, Georgia; Dallas 1, Texas; Fresno, California; Los Angeles 31, California

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New HEAVY-DUTY ELECTRIC PLANT

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Only 272 lbs!

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• Large capacity, compact design, and lightweight aluminum construction are combined in this new, rugged, portable electric plant. Easily carried by two men. Powered by Onan 10 HP horizontally-opposed, two-cylinder, 4-cycle, air-cooled engine. Unusual operating economy. Shipped complete, equipped with four-receptacle outlet box and mounted in tubular-steel guard frame.

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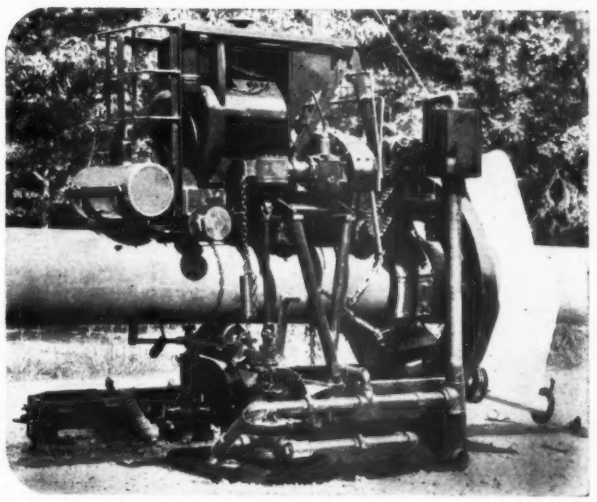
ONAN ELECTRIC PLANTS

WISCONSIN Air-Cooled ENGINE

Wraps Pipe Line



To protect pipe lines against corrosion, this ingenious machine, powered by a Model VP-4 Wisconsin Air-Cooled Power Unit, wraps pipe in asbestos or glass paper.

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Pipe line contractors have found that Wisconsin Engines are best suited for this important operation because of their heavy-duty dependability, low weight and the elimination of "work Holidays" that might otherwise develop from leaky radiators or other cooling and operating hazards. You can depend on Wisconsin Engines for "Most H.P. Hours" of on-the-job service, on any power application within a 2 to 30 hp. range.

WISCONSIN MOTOR Corporation
MILWAUKEE 14, WISCONSIN
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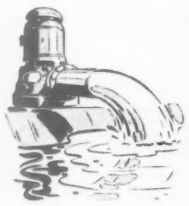

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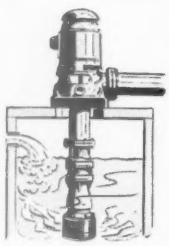

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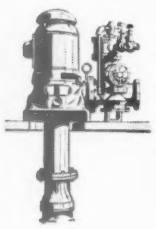

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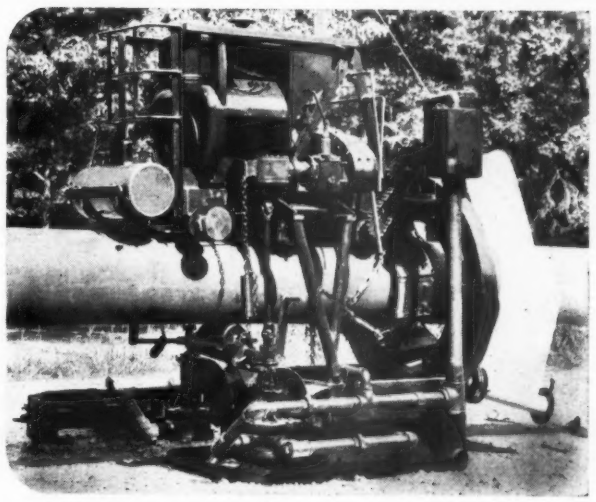

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DIESEL GENERATOR SET

GM diesel 8-268-A, 500 HP, 1200 RPM, dir. conn. to 300 KW-DC, 230 volt GE generator. Cable and switchboard. Like new. Less than half cost. Address Box 78, c/o *The Petroleum Engineer,* P. O. Box 1589, Dallas, Tex.

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Barkley's Directory, the WHO'S WHERE among Producers, this year covers 18 States of Gulf, Mid-Cont. and Rky. Mt. areas. 400 pages of 30,000 listings include all producers and associated personnel. Send $15, under our MONEY-BACK guarantee, for your copy, or write for Sample Sheet E.

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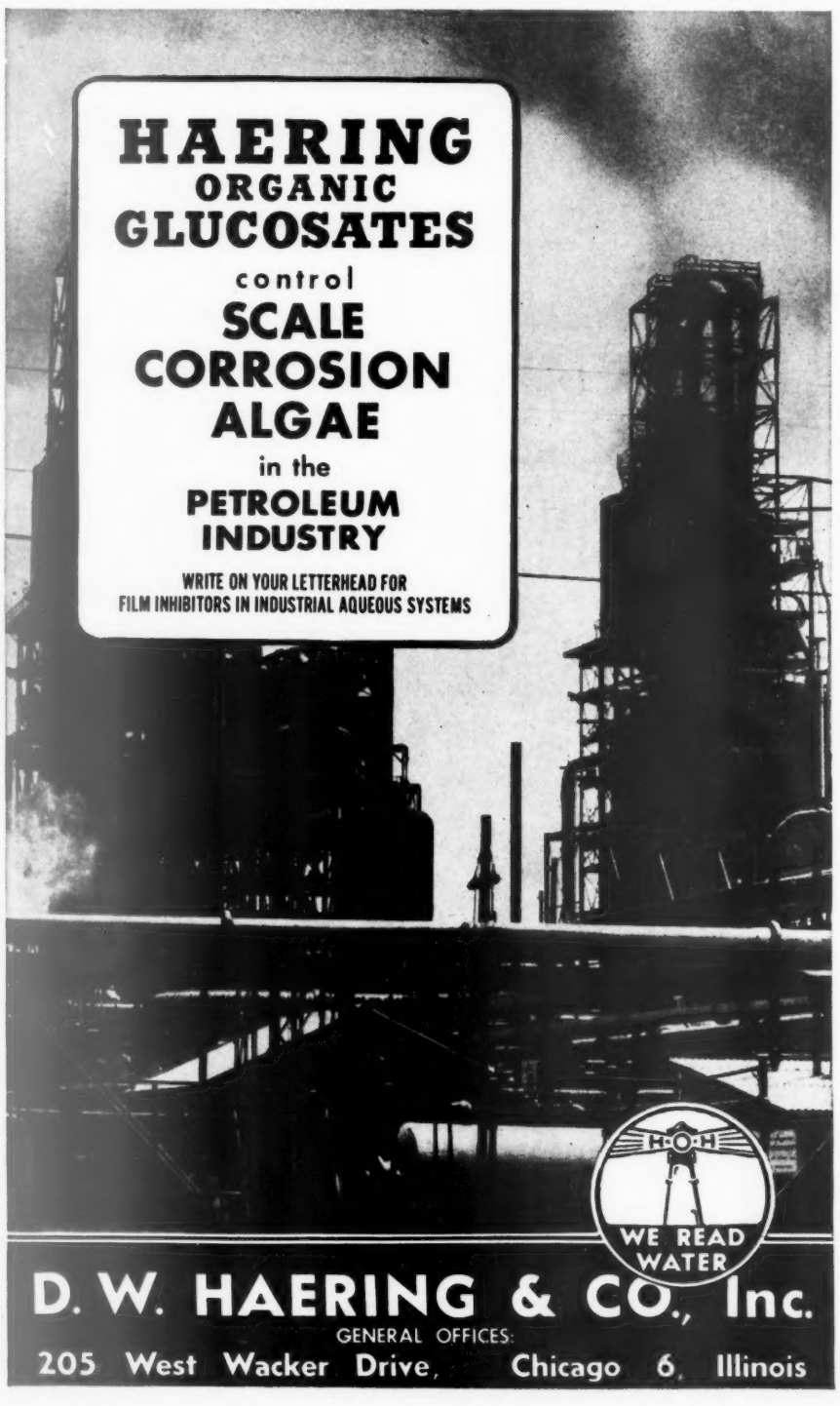
Mechanical and Chemical

A major oil company actively engaged in construction of large synthesis plant, a number of natural gasoline and cycling plants, and other projects has several attractive openings for exprienced engineers. Prefer men with five years or more of successful engineering experience in refinery or gasoline plant design, operation, or construction. Positions are in Engineering and Construction Section, location Mid-Continent area. Salary and responsibility will be commensurate with experience and ability. Address Box 77, care of *The Petroleum Engineer,* P. O. Box 1589, Dallas, Texas.



DESIGNING ENGINEERS

We are expanding our engineering force and need two competent mechanical engineers with broad experience in designing well drilling machinery, either rotary or cable tool types. Will offer excellent opportunities for advancement to capable men who produce results. Permanent positions with progressive organization. Our employees know of this advertisement. Give complete qualifications, experience and salary expected in first letter to Box 79, c/o *The Petroleum Engineer,* P. O. Box 1589, Dallas, Texas.

PETROLEUM RESERVOIR ENGINEER

Graduate engineer with experience in reservoir engineering and practical field applications. Study reservoir problems for Magnolia Petroleum Company operations with the facilities of an electric analyzer. Salary commensurate with ability and experience. Location: Dallas, Texas. Write Magnolia Petroleum Company, Box 900, Dallas, Texas, attention Petroleum Engineering Department, giving all particulars.

SITUATIONS OPEN: Chemical Engineers with three to five years' experience in the operation of petroleum refining distillation units, thermal cracking units or catalytic cracking units for work as Technical Service representatives and Operators of commercial catalytic cracking plants. Kindly send details of experience and education. Snapshot (if available). Address Box No. 59, % *The Petroleum Engineer,* P. O. Box 1589, Dallas, Texas.

An oil field service organization has opening for petroleum engineer in technical oil field service. Applicant must have some experience in oil production and degree in petroleum engineering. Permanent position with long established company. Write giving full details on education, experience, age and marital status. Attach small photograph. Address replies to Box 80, c/o *The Petroleum Engineer,* P. O. Box 1589, Dallas, Texas.

EAST TEXAS FIELD MAPS, 1 in. = 2,000 ft. *Ownership maps, Gasoline plant maps,* showing location and lease connections; *Water maps in colors,* showing encroachment by stages, wells making water, abandoned area, and salt water injection wells. Write *Bob Kyner, Box 976, Ft. Worth, Tex.*

ENARDO MANUFACTURING CO.

Product engineering, designing, developing, manufacturing and marketing. We solicit inquiries regarding equipment to build, particularly for the oil industry.

Box 1647 **Tulsa, Oklahoma**

Named general manager

L. B. Smith, vice president and director of the A. O. Smith Corporation, has been appointed general manager of the Kankakee Works of the company, according to an announcement by W. C. Heath, president. H. F. Detrick, who has held that post since the Kankakee Works went into production, has been carrying a dual responsibility, according to Heath. In addition to building the Kankakee organization from nothing up to a group in excess of 1600 employes, he has at the same time continued to carry on his former duties as president of the Smith Meter Company of Los Angeles, a wholly owned subsidiary of the A. O. Smith Corporation.

L. B. Smith

Sales force expanded

C. F. Faison of Federal Telephone and Radio Corporation, Clifton, New Jersey, affiliate of International Telephone and Telegraph Corporation, is representing FTR's broadcast and mobile communications division, covering Southwest United States. Faison formerly carried on his sales engineering operations for Federal in New England, but will now work out of FTR's branch office at 301 Southland Life Building, Dallas, Texas.

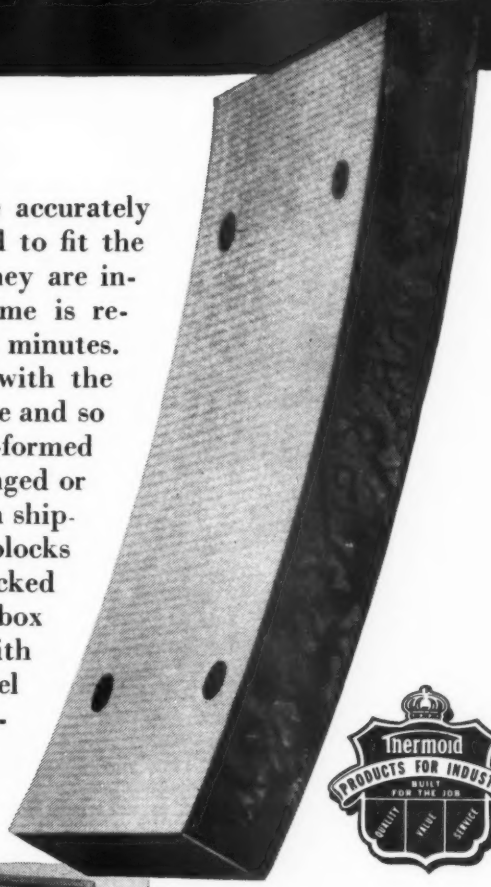
C. F. Faison

Visits West Texas

Tommy Johnston, general manager of M. O. Johnston Oil Field Service Corportion, Los Angeles, California, spent the month of January in West Texas and New Mexico in the interests of expanding service facilities for Johnston Formation Testing and "Shoot-N-Tests," Johnston's new method of gun perforating and combined perforation and formation testing.

Tommy Johnston

Thermoid
Brake Blocks
for ALL Oil Field Drawworks



Built to fit . . .

Thermoid Blocks are accurately formed and jig drilled to fit the machine for which they are intended . . . relining time is reduced to a matter of minutes. Each set is packed with the blocks stacked on edge and so protected that the pre-formed radius cannot be changed or the blocks distorted in shipment. Only enough blocks for one band are packed in a container. Each box is clearly marked with the make and model number of the equipment to be serviced.

No matter what make or model drawworks you use, there is a "Packaged Set" of Thermoid Oil Field Brake Blocks manufactured specifically for your machine. These blocks are designed to provide top operating efficiency and long life, even under the most severe service conditions.

Your oil field supply house will gladly help you with your service requirements.

Thermoid Thermoid Company, Trenton, N.J., U.S.A.
Automotive • Industrial • Oil Field • Textile

Acquires Canadian firm

Stock in the Halliburton Oil Well Cementing Company, Ltd. of Calgary, Alberta, has recently been acquired by Halliburton Oil Well Cementing Company of Duncan, Oklahoma. The Canadian organization will hereafter be operated as a subsidiary of the Oklahoma company, according to John C. Halliburton, president of the parent company.

Officers and directors of the new company will be: R. H. Gibbons, president; John C. Halliburton, vice president, and N. D. McDermid, secretary.

No changes in personnel will be made and the Canadian firm will continue to operate under its title, Halliburton Oil Well Cementing Company, Ltd. R. H. Gibbons, president, of Black Diamond, Canada, will direct the company's operations as he has in the past.

Erle P. Halliburton, Los Angeles, founder of both companies, was sole owner of Howco, Ltd., before its consolidation into the Oklahoma organization.

Halliburton Oil Well Cementing Company is the largest oil field service organization in the world. In addition to its services yearly to the oil industry in some 35 to 40 of the 48 states in the United States, Howco also maintains foreign service branches or representatives in Canada, Venezuela, Peru, Colombia, Kuwait, Saudi Arabia, Borneo, Dutch East Indies, and London, England.

"The same type of oil field service which made Howco the organization that it is today will be given to the oil operators of Canada," says John H. Halliburton, president of the parent company. "The same type of high-pressure equipment and manufactured products will be available in Canada by spring. Any obsolete equipment will be replaced by new, improved models and better service will be established."

Halliburton's services to the oil industry include oil well cementing, formation testing, electrical well logging, acidizing, squeeze packers and plugs, as well as a complete line of sales items such as measuring line equipment, float collars and guide shoes, and Roto-Wall cleaners.

Accurate - Sensitive - Smooth

The MARTIN-DECKER UNITIZED MUD PUMP GAUGE

ACCURACY, sensitivity and smooth, easy reading make the Martin-Decker Unitized Mud Pump Gauge the ideal portable gauge for measuring slush pump pressures. Mechanism runs in an oil bath, eliminating rust or corrosion. Large numerals stand out clearly from 30 feet or more, and readings can be made by simply noting position of gauge hand. Vernier retard movement covers both low and high pressure ranges. Unitized is available in one, three or five thousand pound capacities.

Sealed

For Greater Accuracy and Service

There's no pumping up . . . no adjusting . . . no leaks in the Martin-Decker Unitized. The fluid system is factory loaded and permanently sealed—fluid remains in the unit even during transportation and storage. Installation is fast and fool-proof—accuracy is guaranteed.

YOUR next mud gauge should be a Martin-Decker Unitized. Ask for further information on this rugged, dependable instrument that's designed for years of uninterrupted service on all portable jobs. *Write direct!*

HOME OF THE WEIGHT INDICATOR

MARTIN DECKER CORP.

LONG BEACH, CALIFORNIA

SAN JOAQUIN VALLEY [illegible] CULLEN BAKERSFIELD CALIFORNIA
MID CONTINENT DISTRIBUTOR REED ROLLER BIT COMPANY HOUSTON TEXAS

J. N. Lind promoted

J. N. Lind has been promoted to assistant general traffic manager of The National Supply Company, according to an announcement by C. R. Barton, vice president of the company. He will make his headquarters in the Grant Building, Pittsburgh, Pennsylvania.

J. N. Lind

Lind started working with the company in 1926 as a clerk in the traffic department at Ambridge. He served in the capacity of assistant traffic manager of the Spang-Chalfant Division of The National Supply Company from 1937 to 1945 when he was promoted to traffic manager of the division.

A member of the Traffic Club of Pittsburgh for many years, Lind is now serving on the board of directors of the club.

Bowman promoted

H. Merrill Bowman, who has been district sales manager of the Link-Belt office in Baltimore, Maryland, has been appointed assistant divisional sales manager for power transmission equipment, with headquarters at the company's Pershing Road plant in Chicago.

H. M. Bowman

Bowman is a graduate of Temple University, previous to which he had also attended Drexel Institute of Technology for three terms. After summer employment at the Link-Belt Philadelphia plant, Merrill became permanently attached to that organization in 1932.

The next six years were spent in the engineering, sales, and order departments. He was transferred to Baltimore in 1940 as district sales engineer, and became district sales manager in 1945.

Chain Belt promotes

Chain Belt Company, Milwaukee, Wisconsin, announces the election by the board of directors of three vice presidents.

L. B. McKnight

L. B. McKnight, who joined the company in 1927, has been elected vice president with executive responsibility for the two heavy machinery divisions, conveyor and process equipment and the construction machinery. McKnight was executive assistant to the president of the company.

O. W. Carpenter has been elected a vice president in charge of finance. Carpenter was formerly secretary-treasurer and a director of the Kearney and Trecker Company, and came to Chain Belt Company in 1943.

B. F. Devine started with Chain Belt Company in 1909. He served as sales manager of the construction machinery division, and later as manager of that division. Devine will continue his duties as manager of the construction machinery division.

Joins Cameron staff

John Grubb, former president and general manager of Nuwell Tool Company, has joined the Cameron Iron Works sales department, effective with the purchase of the assets of Nuwell by Cameron on December 1.

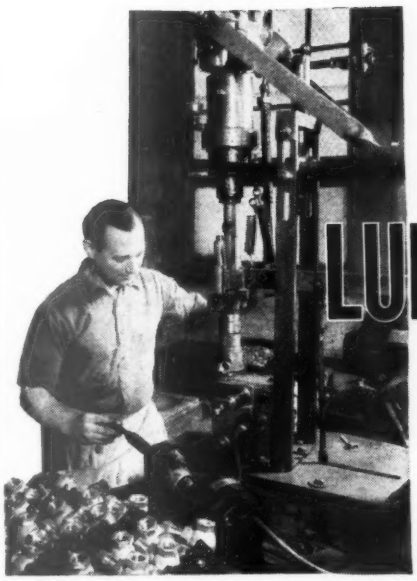
John Grubb

Grubb, who in recent years has been identified with such prominent oil field equipment firms as Baker Oil Tools and Broderick Bascom Wire Rope Company, is well known throughout the industry. In his new position he will specialize in the sale of Cameron-Nuwell cementing shoes and collars and will be located in Houston at the company's headquarters.

Trademark released

Donald Gibb, head of plastics sales division of The Dow Chemical Company, announces that his company has formally released its trademark rights to the name "saran" permitting it to become the descriptive name of the product. Gibb said the action was taken "in the interest of simplifying identification on various plastic materials whose chemical names have for years been confusing to press, trade and consumer alike.

The term saran applies to a series of thermoplastic resins chemically known as vinylidene chloride copolymers originally developed by Dow in the latter thirties and known especially for their resistance to a wide range of chemicals.



ASSEMBLING REQUIRES NO SPECIAL FITTING

• Assembling is greatly simplified by Lunkenheimer precision production . . . parts are so accurately made that special fitting isn't necessary.

LUNKENHEIMER

Precision Workmanship

• • •

SUPER ACCURACY IN EVERY PART

...LONGER SERVICE LIFE

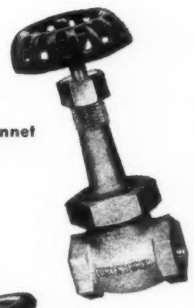


Fig. 2228 Bronze Union Bonnet Gate Valve

Fig. 1430 Iron Body Gate

• You can't fool the maintenance men on valve quality. They know that when a valve has a much longer than average service life, that valve has superior accuracy and precision built into it from handwheel to pipe threads.

Such valves are the only kind that Lunkenheimer has ever produced. For over three quarters of a century, the Lunkenheimer quality ideal has won ever widening acceptance until today it is a recognized tradition in American industry.

Lunkenheimer quality is the balanced combination of many factors. Among them are finest raw materials approved by constant testing and research . . . sound, advanced design . . . highly skilled workmanship . . . absolute accuracy . . . perfect alignment of all parts.

As an inevitable result — wherever you find Lunkenheimer Valves you find maintenance cost records consistently lower.

Your LUNKENHEIMER Distributor

— is an important link in the nationwide Lunkenheimer chain of better, more efficient, more reliable valve service. He is fully equipped to assist in the solution of valve maintenance and operating problems. In addition, he can make prompt arrangements to have a Lunkenheimer Engineer call at the plant whenever technical valve engineering knowledge is required.

ESTABLISHED 1862

THE LUNKENHEIMER CO.

"QUALITY"

CINCINNATI 14, OHIO, U.S.A.

NEW YORK 13, CHICAGO 6, BOSTON 10, PHILADELPHIA 34, EXPORT DEPT. 318-322 HUDSON ST., NEW YORK 13, N. Y.

National Tube promotes

Appointment of E. E. Smith as manager of sales of National Tube Company for the Southwestern area, with offices at Dallas, Texas, was announced by H. J. Wallace, general manager of sales of this U. S. Steel subsidiary.

E. E. Smith

The announcement was made at a district sales conference attended by managers of National Tube Company divisions of Dallas, Denver, Houston, New Orleans, and Tulsa. Smith will have general supervision over these five divisions.

Also announced was the appointment of James R. Boax as manager of sales at Houston, succeeding Smith.

A graduate of Carnegie Institute of Technology, Smith spent several years in the engineering and operating departments of the company's National Works at McKeesport, Pennsylvania, before going to Texas as a field engineer in 1929. He served as director of service for National Tube's sales department, was made manager of sales at Tulsa in 1943, and went to Houston in the same capacity last year.

Boax is a graduate of Syracuse University and has had 17 years' experience with National Tube and Oil Well Supply Company, also a U. S. Steel subsidiary. After four years with the operating department at National Works, he became a field service engineer in 1934. Subsequently he was a salesman for National Tube in Tulsa, district manager of tubular sales for Oil Well Supply Company, assistant priorities administrator of National Tube during the war, and recently a salesman in the Houston office.

Munn joins Rockwell

R. J. Munn has joined the sales staff of the Nordstrom Valve Division, Rockwell Manufacturing Company. He has been assigned to the Houston office where he will work under the direction of C. K. Madison, district manager.

R. J. Munn

Munn was formerly an Army pilot, having spent three years as a commissioned officer in the U. S. Army Air Corps. Prior to the war he studied engineering at Texas A & M College. He has had recent experience in the oil fields where he worked in various capacities on drilling rigs.

Munn will make his home in Corpus Christi and devote most of his time to sales and service on Nordstrom Valves.

California representative

With appointment of Leo S. Case, Long Beach, as California sales representative, Cardwell Manufacturing Company, Inc., announces a change in method of representation in California for sales and service parts stocks. Until recently the oil field equipment manufacturing concern was represented in California through a dealership, but under the new program, the direct representative plan will be used. Associated with Cardwell Manufacturing Company, Inc., since last November, Leo Case was formerly sales engineer for the Buda Engine Sales and Service Company in Tulsa for five years.

Leo S. Case

Leo Case's address is 3504 Atlantic Avenue, Long Beach; mailing address is P. O. Box 7006, Bixby Station, and his phone number is Long Beach 4-7996.

Beside's Case's representation in the new Cardwell program, Apex Equipment Company of Long Beach and Bakersfield will handle complete stocks of Cardwell parts. The long Beach address is 3504 Atlantic Avenue. The Bakersfield address is Rosedale Highway, P. O. Box 1733.

Announcing to the Petroleum Industry

ATWOOD AND MORRILL CO.

SALEM, MASS.

Manufacturers of Special Valves and Control Equipment
For Oil Refineries, Chemical Plants,
Central and Industrial Power Plants

- **TURBINE AND CONDENSER EQUIPMENT**
- **AIR AND HYDRAULICALLY OPERATED VALVES**
- **FLOOD CONTROL VALVES**
- **COMPLETE REMOTE CONTROL SYSTEMS AIR OR HYDRAULICALLY OPERATED**
- **EMERGENCY AND PROTECTIVE VALVES**

MAIN OFFICE & WORKS
SALEM, MASS.

BRANCH OFFICES
507 5th Ave., N. Y. C. — 12th & Walnut St. Bldg., Kansas City, Mo.

Engineering changes

Appointment of August R. Maier as director of engineering and Alexander Quayle as chief engineer of Oil Well Supply Company is announced by Fred F. Murray, president of this U. S. Steel subsidiary. Maier's new headquarters is in Dallas, Texas. Quayle will remain in Oil City, Pennsylvania.

A native of Germany, Maier was naturalized as an American several years after his graduation from Stuttgart Institute of Technology. He became associated with the oil industry in California, and joined Oil Well in 1930 in Braddock, Pennsylvania. He was transferred to

August R. Maier

Alexander Quayle

Dallas as assistant chief engineer in 1932 and was made chief engineer 1936.

Quayle is a native of New York. He was graduated from Stevens Institute of Technology before joining Oil Well as a field service engineer.

Fred Cooper killed

Fred E. Cooper, president of the Fred E. Cooper Company, Tulsa, Oklahoma, was killed in a plane crash in the Gulf of Mexico February 6 while flying his own plane. His body was washed ashore near Brownsville, Texas, from where he had taken off to fly to Tampico, Mexico. Unfavorable weather is said to be the cause of the accident.

Fred Cooper

Cooper was internationally known in oil circles. He developed an oil field tractor for the Rumley company in the early 1920's that became a heavy seller, after early difficulties in getting companies interested. In 1925 he established himself in Tulsa.

The Rumley company was merged with Allis-Chalmers Manufacturing Company, and Cooper became the world distributor of all oil field equipment made by the company. In addition he distributed his own equipment, part of which Allis-Chalmers made. This included a tractor with special features, patented by Cooper.

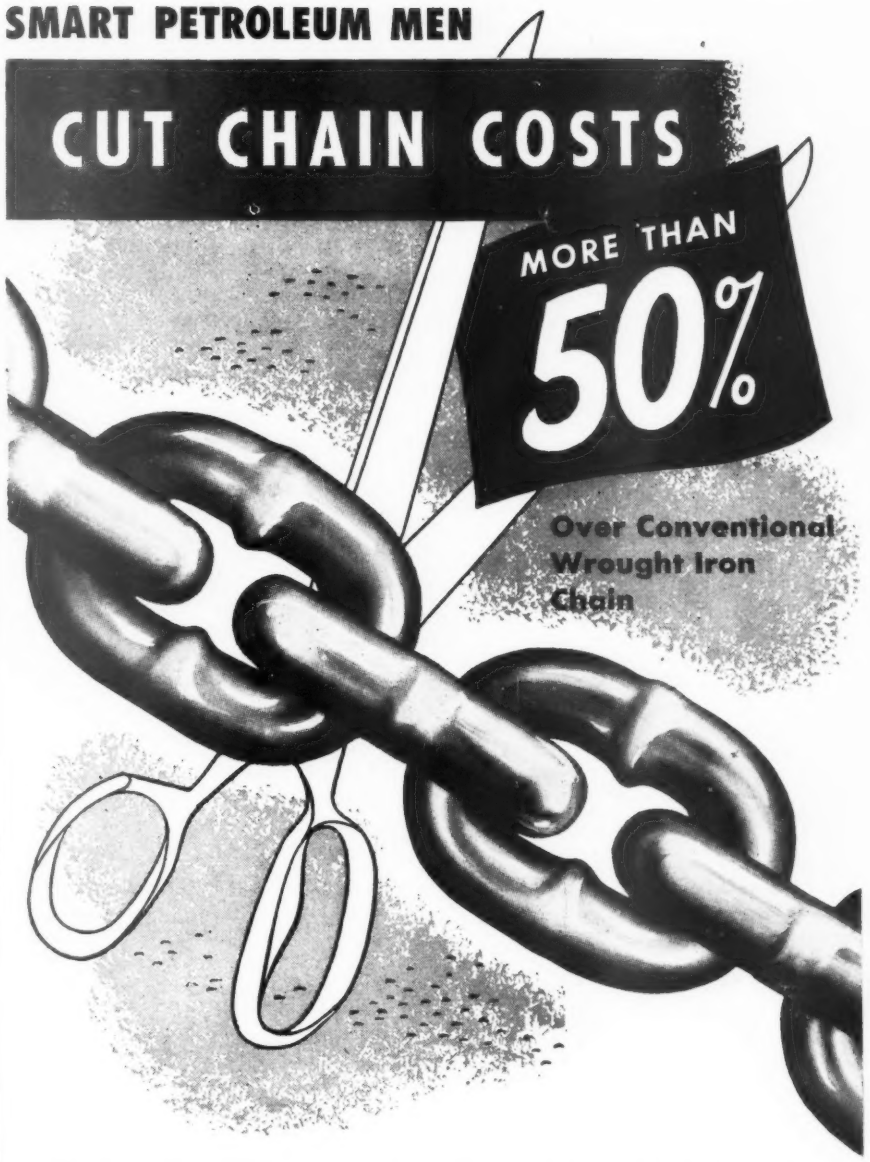
The "flying salesman" was a Kansas native. He went to Oklahoma with his father to make the Cherokee Strip run in a covered wagon. In 1914 he opened a bicycle shop in Ponca City and later went into the automobile business. Then he became interested in tractors and began his spectacular career in oil equipment.

SMART PETROLEUM MEN

CUT CHAIN COSTS

MORE THAN 50%

Over Conventional Wrought Iron Chain



IT'S possible to cut chain costs 50%, when you use TM Alloy Steel Chain. It has five to fifteen times the life of wrought iron chain (depending on the type of work)...because it has twice the tensile strength... far greater resistance to shock, to grain growth and to work-hardness. It never requires annealing. And it's tougher... Brinell Hardness Tests show 270 to 300. It all adds up to less than half the replacement costs...less than half the maintenance costs and twice the safety factor of ordinary chain. TM Alloy Steel Chain is quickly recognized by its double weld. For specifications and prices contact your local mill supply distributor today or write the factory direct.

S. G. TAYLOR CHAIN CO.
Dept. 0-2, Box 509, Hammond, Ind.

TAYLOR MADE ALLOY Chain

"THE BEST BY TEST SINCE 1873."

Pupil: Do you think it's right to punish folks for things they haven't done?

Teacher: Why, of course not, Willie.

Pupil: Well, I didn't do my home work.

* * *

The hunter came panting up to one of the party.

"Just met a great big bear in the woods," he said breathlessly.

"Good!" said the other. "Did you give him both barrels?"

The hunter wiped his perspiring brow.

"Both barrels!" he returned, "I gave him the whole gun!"

* * *

"Do you act toward your wife as you did before you married her?"

"Exactly. I remember how I used to act when I first fell in love. I used to stand in front and look at her house, almost afraid to go in. Now I do the same thing some nights."

* * *

Junk Man: Any old beer bottles you'd like to sell, lady?

Old Maid: Do I look as though I drink beer?

Junk Man: Any vinegar bottles you'd like to sell?

* * *

Gert: Do you think my hands show any signs of toil?

Myrt: The one with the engagement ring on shows that you've been working.

The Cavalry recruit was instructed to bridle and saddle a horse. Ten minutes later the sergeant-major came along for his mount and found the recruit holding the bit close to the horse's head.

"What are you waiting for?" he roared.

"Until he yawns," answered the recruit.

* * *

The landlord was making one more attempt to collect rent from his tenant, a poet.

After the tirade the poet spoke up: "Why, sir, you ought to pay me for living here. In a few years' time people will be looking up at this miserable attic and saying: 'That's where Miller the poet used to live.'"

"Well, you needn't wait all that time," answered the landlord. "If you don't pay me by 11 o'clock they can say it tomorrow."

* * *

First Rousty: A woman's greatest attraction is her hair.

Second Rousty: I say her eyes.

Third Rousty: I'd say her smile.

Fourth Rousty: What's the use of sitting here lying to each other?

* * *

A tourist, traveling through western Kansas, saw a man sitting by the ruins of a house that had been blown away, and stopped to ask:

"Was this your house, my friend?"

"Yep."

"Any of your family blown away with the house?"

"Yep, wife and four kids."

"Great Scott, man, why aren't you hunting for them?"

"Well, stranger, I've been in this country quite a spell. The wind's due to change this afternoon. So I figure I might as well wait till it brings 'em back."

* * *

Breathes there a man with a soul so dead, who never has turned his head and said, "Hmmmm, not bad!"

* * *

Sign in a restaurant: "Our silver is not medicine. Don't take it after meals."

* * *

The chief of police of Dinksville was also Dinksville's veterinary surgeon. An agitated woman called up his home.

"Do you want my husband in his capacity of veterinary or chief of police?" asked the chief's wife.

"Both!" came the reply. "We can't get a bulldog to open his mouth; there's a burglar in it!"

* * *

On one of the billboards featuring Smith Brothers cough drops, the slogan reads: "Take one to bed with you." Underneath some wag wrote: "I wouldn't sleep with either of 'em."

* * *

"Young lady, I'd like to give you a complete physical examination."

"But Doctor Jones examined me last week and found me perfect."

"Yes, that's what he told me."

* * *

"Goodness, Mary, what makes you so hoarse?"

"I just talked my husband out of a dollar."

* * *

The cannibal king looked at the beautiful young woman and at the big cooking kettle under which a fire was being made ready. He turned to one of his tribe and said: "You know, I believe I'll have breakfast in bed."

* * *

"Who was Tallyrand?" asked the professor.

"A fan dancer, and please cut out the baby talk," answered the bright pupil.

* * *

"I wonder if you could help a girl in trouble?"

"Certainly, what kind of trouble do you want to get in?"

* * *

Wife: The doctor said at once that I needed a stimulant. Then he asked to see my tongue.

Husband: Good heavens, I hope he didn't give you a stimulant for that, dear.

* * *

Shopper: I want to buy an alarm clock, one that will awaken my husband without arousing the whole family.

Clerk: Sorry Madam, but we haven't any like that. All we have are the ordinary kind that wake up the whole family without arousing father.

ANSWERS TO THE QUESTIONS you've asked about any packer?

The Baker Retainer Production Packer is completely drillable. You will never have to "mill up" a Baker Packer.

Yes, the cast iron construction of the Baker Packer is far more resistant to corrosion than the steel casing in which it is set.

Not the Baker Retainer Production Packer which virtually becomes a part of the casing when it is set. The tubing can be pulled and run-in again as often as is necessary.

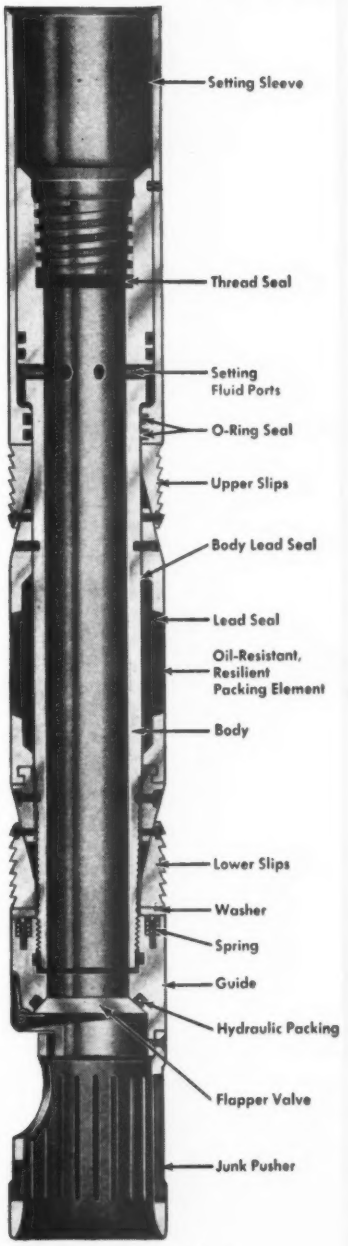
Yes; Baker Packers are anchored against either upward or downward movement by two full sets of opposing slips.

When it is desirable, the tubing can be suspended in tension, thus eliminating the possibility of "corkscrewed" tubing which would hinder or prevent dropping pressure bombs, or other similar operations.

Not the Baker Retainer Production Packer, which is equipped with a positive-sealing, flapper type back-pressure valve. This flapper valve opens readily to permit the downward passage of tubing or tools, but closes instantly to hold safely against back-pressure when the tubing (or tools) are being removed from the well.

Yes; to practically all applications, and to all operating procedures. Single-zone or two-zone hook-ups are possible to meet any production requirement. The Baker Retainer Production Packer also is ideal for water-injection or flooding re-pressuring, re-cycling, testing, acidizing, gas-lift, and many other applications.

The Baker Retainer Production Packer (Product No. 415-D) is made by Baker Oil Tools, Inc., and Baker representatives are stationed in all active areas to give you prompt and intelligent service. Get in touch with your nearest Baker man today.



BAKER
RETAINER PRODUCTION
PACKER

Otis Engineering completes shop and plant expansion

H. C. Otis, president, has announced the completion of a construction program that has increased usable manufacturing, testing, and shipping space for Otis Engineering Corporation, Dallas, Texas, by 138 per cent, at a cost of approximately $50,000.

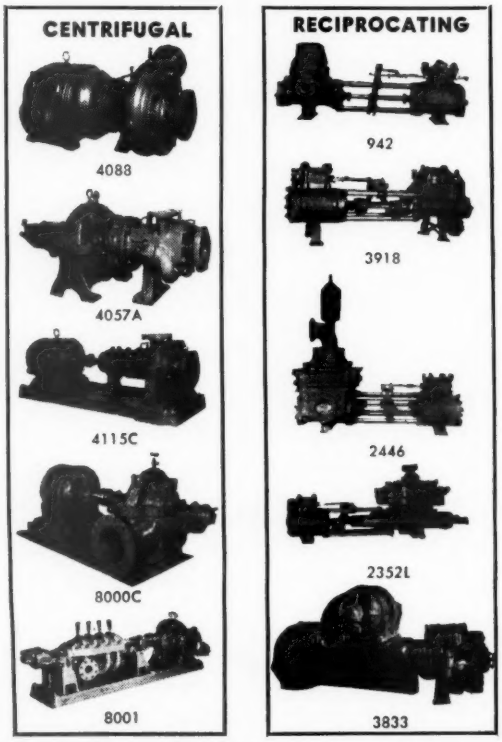
Building alterations and additions completed during December, 1947, called for the construction of a separate and enclosed tool room, one of the most completely modern enclosed grinding rooms in the Southwest; a separate tool crib, inspection facilities, and welding rooms. Heating and ventilation systems throughout the building have been rearranged and capacity increased; additional bridge cranes have been installed to service the entire storage, shipping, and receiving area. Wash room, dressing room, and shower facilities have been enlarged, while ventilation and fire protection equipment has been added to the heat-treating department. Modern testing devices have been installed in the testing room, the latter being used for performance analysis of Otis tools and equipment. The latter is in addition to the 125-ft deep test well located outside where actual surface and subsurface pressure conditions are simulated up to 8160 psi test pressure. All space formerly used for tool and equipment assembly has been enlarged, and production set-ups and material flow have been rearranged to eliminate excessive material handling.

Exterior of the building additions were planned to conform with the original construction of painted brick and windowed walls. The parking area has been increased some 50 per cent, graded and graveled, with plans to pave the area as soon as weather conditions are favorable.

This photograph shows the recently completed addition to the plant building of Otis Engineering Corporation. The new construction, marked by awnings in front of the rear wing and duplicated on the opposite side, increases usable manufacturing, testing, and shipping space by 138 per cent.

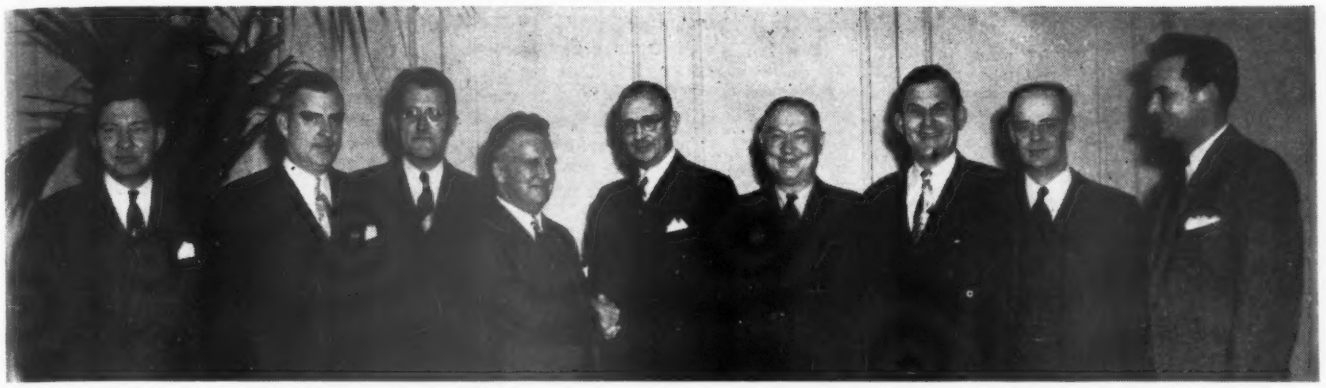
ESTABLISHED 1869
DEAN BROTHERS PUMPS INC.
INDIANAPOLIS IND.
323 W. TENTH ST.

PUMPS
BUILDERS OF OUTSTANDING PUMPS SINCE 1869



BRANCH OFFICES: NEW YORK HOUSTON

Officers of New York Chapter Nomads for 1948



Left to right: Stewart D. Beckley, secretary; Henry J. McAdams, vice president; James W. Reed, regent; A. V. Simonson, regent (retiring president); Val R. Wittich, Jr., president; W. D. Robinson, sergeant-at-arms; Russ V. McIntire, assistant secretary; Joseph B. Roberts, Jr., treasurer; Charles P. MacDonald, Jr., assistant treasurer. Marvin D. Rasher, assistant sergeant-at-arms, was not present.

Carl Asendorf succumbs

Carl F. Asendorf, 69, manager for American Meter Company's Chicago plant, died at St. Joseph's Hospital, Chicago, recently. Asendorf was born October 18, 1878, in Baltimore, Maryland.

C. F. Asendorf

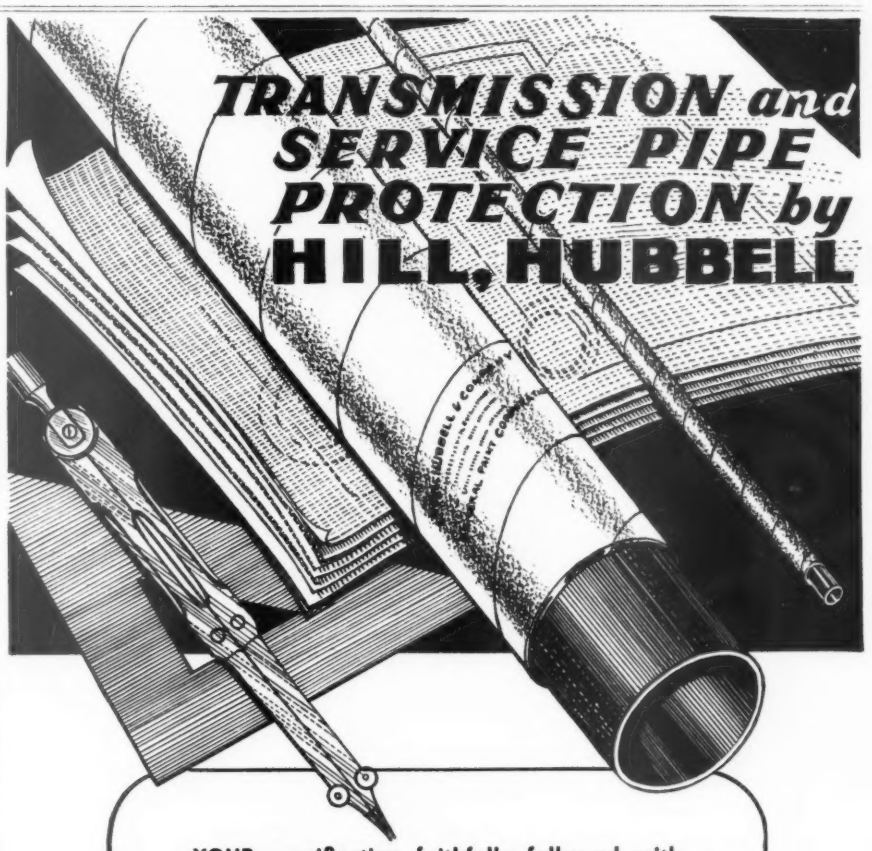
Asendorf began his career in the gas industry in 1895 with the Maryland Meter Works at Baltimore. He was associated with the American Meter Company first in Baltimore and since 1902 in Chicago. There he had full charge of factory operations since January 1, 1926.

Salter promoted

At the district sales managers' meeting held at Houston on January 19, the management of the A-1 Bit and Tool Company announced the appointment of T. Howard Salter as assistant sales manager. A product of Hardin County, Texas, Salter served from 1918 to 1932 as roughneck and driller, and then entered the oil field supply business with the Houston Oil Field Material Company as a salesman in the Louisiana district; from 1939 to 1945 he was district manager in Louisiana and Mississippi for Bethlehem Supply Company. After two years with Hunt Tool Company, he entered the employ of A-1 Bit and Tool Company on June 13, 1947.

T. H. Salter

Salter will have headquarters in Houston but will supervise sales in Louisiana and Mississippi.



YOUR specification faithfully followed with proper enamel and felt wrapper application to manufacturers rigid requirements and our time proved "unit loading method" warranting satisfactory delivery to rail destination, point up a few of HILL, HUBBELL'S unexcelled factory processed coating and wrapping services.

Special design machinery for cleaning—priming—coating—and—wrapping all standard sizes of pipe from ¾" nominal, to 30" O. D., assures positive control in each step of application.

Let us help solve your corrosion problems.

Hill, Hubbell and Company
Division of GENERAL PAINT CORPORATION
3091 MAYFIELD RD. CLEVELAND, OHIO.

Improvement program

The Cooper-Bessemer Corporation, Mount Vernon, Ohio, manufacturers of diesels, gas engines, and compressors, has embarked on a $600,000 improvement program, in an effort to increase its production of equipment sorely needed to help alleviate the shortage of natural gas.

Authorization for the program was granted by the company's board of directors, B. B. Williams, chairman of the board announced.

The program calls for the purchase of $325,000 worth of new machine tools for its Grove City, Pennsylvania, plant and the expansion of its foundry facilities, and about $275,000 for equipment for the Mount Vernon plant.

The machinery, which is largely to replace present equipment, consists of large facing tools and boring and drilling equipment. Company officials estimate that production will be increased by from 25 to 30 per cent as a result of these expenditures.

Cooper-Bessemer is currently producing several sizes and types of compressors for use on natural gas pipe lines and in plants that process gas for the extraction of gasoline and fuel oil. Included among these compressor types is the new GMW, said to be the largest of its kind in the world. Six of these huge new engines are already in service in cross-country pipe lines that bring natural gas to the Eastern and Mid-Western sections from the Texas fields.

PPP officers

For the third successive year J. E. "Jim" Gosline, Standard of California, has been elected president of Petroleum Production Pioneers, the fast growing organization of petroleum field veterans and their aides in the equipment and supply business. Elected to represent the pioneer members on the board of directors were W. L. McLaine, honorary president; Jud Hillman, honorary vice president; Cyrus Bell, and F. F. Hill.

Other officers elected by the executive board were: E. L. Decker, vice president; Richard Sneddon, secretary; C. S. Perkins, treasurer; O. W. Morgan, Jr., sergeant-at-arms; Ted Sutter, historian. The full membership of the board is as follows: J. E. Gosline, Standard of California; C. S. Perkins, Union Oil Company; S. H. Grinnell, Key Contractors; B. Bronzan, Baash-Ross; Ted Forsyth, Emsco; Warren Johnson, Standard of California; A. S. Hayes. Hayes and Sprague; Jud Hillman, Hillman-Kelley; W. L. McLaine, General Petroleum Corporation; F. F. Hill, Union Oil Company; O. W. Morgan, Jr., Byron Jackson Company; E. L. Decker, Martin-Decker Corporation; Cyrus Bell, Loffland Bros. Company; L. George Trembley, Howard Supply Company; Ted Sutter, Baker Oil Tools, Inc., and R. Sneddon, *The Petroleum Engineer*. Bob Roberts of Standard of California is chairman of publicity.

Personnel of the working committees will be announced in the near future.

Coordinate activities

As a focal step in streamlining the extensive technical and laboratory operations of The M. W. Kellogg Company, process engineers, H. R. Austin, president of that company, announced the appointment of Dr. W. E. Hanford, scientist, to the newly created post of director of petroleum and chemical research. Dr. Hanford joined the Kellogg organization in October, 1946, going to that company from General Aniline and Film Corporation where he was director of research.

Originally confined to one or two basic fields, the research activities of the Kellogg company have expanded in recent years until today they encompass virtually all of chemical science.

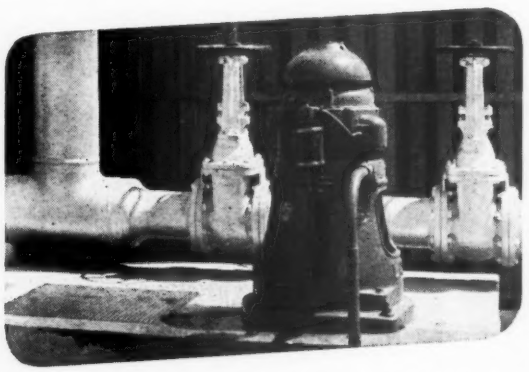
"These numerous diverse research operations," Austin stated, "are now being coordinated under the overall direction of Dr. Hanford.

Opens sales office

Opening of an Oil Well Supply Company sales office at Bartlesville, Oklahoma, with Charles A. Baker in charge, is announced by M. Barkhurst, Mid-Continent division manager for this U. S. Steel subsidiary. Baker has been manager of the Beaumont, Texas, store since September, 1938.

He joined "Oilwell" in 1928 and served in stores at Tonkawa, Oklahoma, Blackwell, Oklahoma, Winfield, Kansas, and Eldorado, Kansas, before going to Beaumont as assistant manager in 1935.

COOLING TOWER WATER



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Any size—any capacity—against any head, Layne Well Water Systems always give peak performance. For further interesting details and facts, address Layne & Bowler, Inc., General Offices, Memphis 8, Tennessee.

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VERTICAL TURBINE Pumps

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HEADQUARTERS FOR OIL MEN

TULSA'S LARGEST FINEST HOTEL

THE MAYO

Petrolic Personalities

By DICK SNEDDON

Reports from Dallas indicate that John Murrell, manager of the De Golyer and MacNaughton layout, took off recently from Miami on a reconnaissance junket into Caracas and other centers of Latin American "culchah." John is one of these perennial travelers who, the minute he sees a globe, starts making arrangements to girdle it. He has already visited most of the world's oil fields and is as familiar a figure in Saudi Arabia as Ned Brown, the NAODC prexy. After observing the desert transportation system in operation and becoming hep to its effluvium, John simply can't for the life of him understand why anyone should want to inhale a camel. However, he is scheduled for another trip to the Middle East anon or a little later and will likely be doing some more research on this problem. Several others in the same firm will streak out to foreign fields this year, among them, Hank Gruy, who, as we write, is suffering atrociously from all the injections and inoculations to which he has had to submit himself in order that he might visit in certain South American areas. The shots have given Hank the most flexible temperature in Dallas. One day he is colder than a beagle pup's nose. The next he has more degrees than Ralph Arnold. It is amazing, really, what these scientists are willing to endure for the privilege of carrying light into the dark corners of the earth.

●

And while we are messing around in the higher geological strata, we might remark that some years ago, the editor of *Pathfinder* said that if he were asked to name the brainest man he ever met, he would have to give the palm to Everette Lee De Golyer, an "Oklahoma and Texas oil scientist who had just been awarded the Fritz medal by AIME." Some pretty famous people have been Fritz medalists, among them Orville Wright, the pioneer flyer whose death was announced a few days ago; Thomas Edison, the man who invented the phonograph so that we would all sit up late and use his other invention, the electric light; Alexander Graham Bell, the star of a motion picture by the same name, and other equally competent and equally famed scientists. Returning to "Dee," however, the writer gave him credit for having "by his own deductions—his own mental processes" developed a new method of discovering oil pools. This was, of course, the application of the seismograph to the field of petroleum geology, which at the time the article appeared had already been responsible for the addition of many billions of barrels of oil to known world reserves. That was somewhat ancient history so far as we were concerned, but the human aspects of the story we didn't know, and we were more than pleased to learn that Everette Lee "had an almost fanatic devotion to the history and lore of the Southwest," and, indeed, knew more about the life and exploits of Billy the Kid than did Billy himself. In fact, we were given fair warning in this article not to tangle with the eminent geologist on *any phase* of Texas development unless we knew what we were talking about, so at last it comes out—that's why we have never argued with Everette Lee on the history of the Lone Star State.

●

Diverging briefly here, on a recent Saturday, we barged out to Santa Anita, California's newest race track with Mr. and Mrs. Hank Struth, a great inward quaking, and ten dollars in currency. When we barged back into town again several hours later, we still had Mr. and Mrs. Hank Struth and the great inward quaking, but the ten dollars were gone—carried away, alas, on the soft nose of a futile equine that couldn't have won if it had been fueled with triptane. But although we failed to add a single simoleon to the family exchequer, we engaged in some high adventure, the which may be mildly interesting to those who have tagged with us so far. Approaching the Santa Anita parking lot with the 10,000 other cars, we reached deep into our jeans for two bits to lay on the persistent palm of a parking attendant, and crunched sickeningly into the rear of the car ahead. Even through the exceedingly dirty window in the

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back of his jalopy we could distinctly see the lips of the driver shaping the familiar but humiliating words, "You blankety blank so and so, why in the such and such don't you bad word look where you're going?" This so embarrassed us that we failed to note where we were parking, and when we came out of the track after the sad demise of our tenspot, there they were—as far as the eye could reach, and if we do say it ourselves we have an unusually far reaching eye, acres and acres and acres of automobiles, and all we could remember was that one of them was ours. Which or where was a gamble that made picking a winning horse look like a pipe. More by good luck than good guidance we found the heap just before midnight, crawled in, and drove dejectedly away. Before leaving this fascinating subject, we might remark that the far eastern end of the club house is an elevated section that is reserved for people who can afford to have race horses of their own. Through high-powered binoculars, when there is no smog, one can distinctly see Reese Taylor, Bob Eiche, and other petrolic luminaries sipping delectable fluids from frosted glasses, as they languidly give orders for the running of the next race.

Saying which, we return again to Dallas—and Jake Hamon, who we are told is busier than a radio scenarist writing a folio of speeches while his fourteen secretaries stand alongside sharpening pencils. Jake is in his second year as vice president of production for the American Petroleum Institute, and being one of the best after dinner speakers since William Jennings Bryan, every oil organization in the Western Hemisphere is planning a dinner for Jake to speak after. One of the fundamental reasons for his outstanding success in this department is his confirmed belief that a platform orator who doesn't strike oil in a very few minutes should quit boring.

And, now, we have it on good authority that D. V. Carter, chief petroleum engineer of the Magnolia Petroleum Company, has planted a flock of acorns on his White Rock estate, which reminds us of the lad who bought a couple of acorns from the seed department of a large general store, and inquired of the clerk, "Are you sure these will grow into big strong oaks?" "Oh, yes," replied the clerk, "No doubt of it." "Well," said the shopper, "Better give me a hammock, too."

Lewis Finch, an active member or the North Texas AIME, resigned his vice presidency of the Fort Worth Engineers Club, pulled up stakes, and lighted out for Odessa, where henceforth he will officiate as district superintendent for Stanolind. Lewis will be remembered for his interesting and accurate definition of a potential, to wit: A well potential is that hypothetical quantity of oil which a well must yield, so that if at any time production must be curtailed in the interest of the indusry, the owner will still have an allowable slightly in excess of what the well will do when it is wide open. Which all sounds if possible both rational and complicated.

In any case, it frees us to discuss the adventures of Ralph Maddox of Big West Drilling Company, affable secretary of the Petroleum Engineers Club at Dallas. From what we hear, at a recent consorting of the members, Ralph did himself proud by presenting an excellent platform dissertation, entitled, "Petroleum Engineers, Accountants, and Income Tax Problems." Having no information on this speech except that it was right well done, we are unable to provide any excerpts, but we have been wondering if petroleum engineers and accountants generally won't object to being grouped in the same distasteful category as income tax problems. Actually, these job titles don't necessarily mean much. A very competent accountant of our acquaintance has never yet been able to account for a blonde hair that his brunette wife found on his shoulder one night after an API meeting.

Our California operatives tell us that Charley Perkins, a popular member of the 7600 out here abouts, is, as we write, skimming down to Mexico City, whence he will veer over to San Jose, Costa Rica, and via Buenos Aires will eventually roost for some six weeks in Asuncion, Union Oil Company's Paraguayan headquarters. Charley is treasurer of the Petroleum Production Pioneers, and is also a pumpkins of no mean order in that obscure aggregation, known as the Nineteeners. Out at the golf course, the caddies affectionately call him Lightning

Perkins—because lightning never strikes twice in the same place. And here might be as good a spot as any to say a word in tribute to Charley's boss—Buck Weaver, Union's manager of purchases, and as clean a lad, morally, mentally, and physically, as you'd ever find, even if you organized a posse to hunt one down for you. Buck could have been just as big a success in the ministry as he has been in the oil business if that had been his choice of a career, for he has all the attributes of a teacher, and the strength of conviction to live as he believes one should live. A "gentleman and a scholar," we'd say, and one whom it has been a pleasure to know for many years.

●

The ingenuity and adaptability of the oil tool manufacturer has been pretty well exemplified in the invention of a starting gate by E. M. Smith. And just in case anyone should ask you what is the relationship between the design of new oil tools and the perfection of a starting gate for horse races, we'll tip you off to the answer—they both take brains. The whole thing is a convincing proof of the very things that we are trying so hard these days to prove to the ultra leftists—that there is no monopoly of ideas, that there is still plenty of opportunity for the exercise of ability and energy. A reputable oil tool manufacturer invents a starting gate for which the racing fraternity goes hook, line, and sinker. What does that prove, says you. To us it simply proves that E. M. Smith is smart people, for besides making good tools he can also make good starting gates. But we sure wish he could perfect some sort of projection device to launch the culls on which we invariably lose two dollars and a perfectly good temper.

●

Stumbled into Frank Gilstrap, the exporter, in downtown Los Angeles the other day, as he was playing escort to an interesting gentleman from Maracaibo, one Ten Eyck Hull, a safety engineer with Shell Caribbean, here on a combination business and pleasure trip. While in the United States, he will consult on safety methods and appliances, and to that end will make the round of the Shell installations. "TE" as he is known to his intimates, hails originally from San Antone, Texas, and still has faint traces of Texan inflections in his speech. His wife and 7-year-old daughter, Iris, are accompanying him, and they will also return to Maracaibo about the end of March if there is no change in present plans. TE, incidentally, is an enthusiastic philatelist, specializing in American and Venezuelan issues, and was able to explain to our intense gratification that the musty smell in most postoffices is caused by the dead letters. Needless to say, after that we gave him the stamp of approval.

●

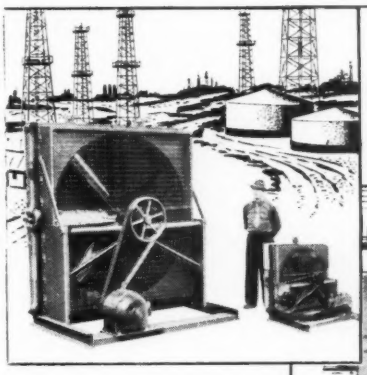
We can't help feeling sorry for Ed Hagstette, Baroid's expert on barge drilling, and one of the oil industry's most eligible bachelors, who despite the fact that he has been transplanted from the Gulf Coast to within easy reach of Hollywood, can't even work up a mild interest in the screen extras. They say even when he was in Paris, France, the eager advances of the mamzelles left him colder than a chocolate sundae. The poor guy simply must have a southern gal or none. He occasionally goes out on the golf course seeking congenial companionship to take his mind off his heart troubles, but he can't even get that kind of companionship, because he has a nasty slice, and after his opening tee shot is rarely seen again. There may be no truth in this, but it is reported that he has among his clubs the very spoon that was used at the Boston Tea Party. And if this can be verified, we would certainly suggest that it be turned over to Ted Sutter, along with Tom Taggart's wooden putter, as two of the industry's most historically interesting tools.

●

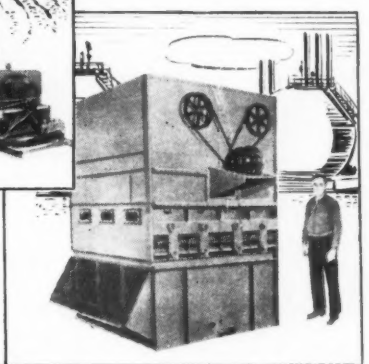
And for the last minute roundup, we note that Art Flint, Shell Company industrial relationist, recently bagged the highest of all cribbage hands in a game with some friends. Art drew three fives, a jack, and the five of the same suit as the jack on the cut, which netted him a grand total of 29, because of which he will be known in future as His Nobs Art Flint. Incidentally, Flint is a very hard name to pronounce.

A production man who shall be nameless was telling us about his unsuccessful attempts to trap a gopher that was wrecking his front lawn. Up walked Nick D'Arcy about that time, and sezze, "The trouble is you gotta be smarter than the animal you're trying to catch."

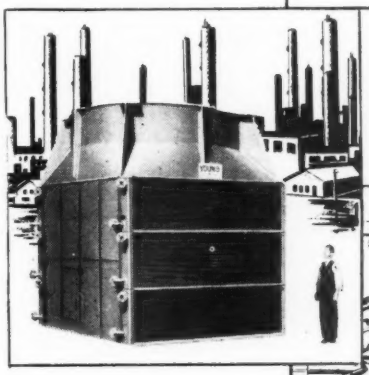
FOUR FAVORITES FOR COOLING
from Well to Refinery



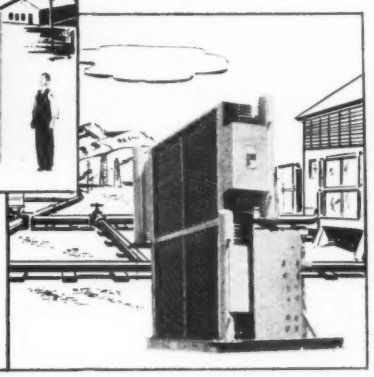
Jacket Water Coolers



Evaporative Coolers



Vertical Air Discharge Coolers



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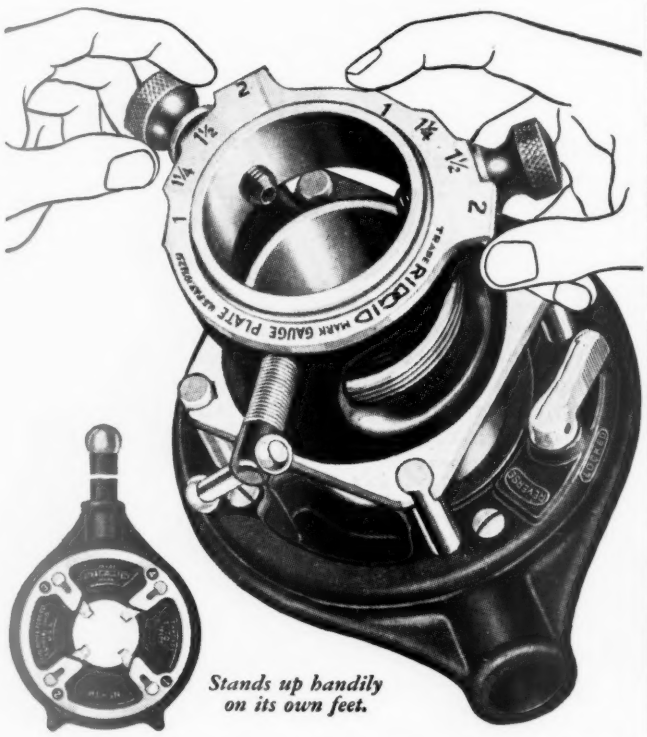


Stands up handily on its own feet.

RIDGID
WORK-SAVER PIPE TOOLS
THE RIDGE TOOL COMPANY • ELYRIA, OHIO

Met Pete Schaafsma in Oscar Shove's office at Shell a short time agone. He is an equipment engineer from Dutch East Indies, and was dropping in for a look around *en route* to Holland. Asked him if he was related to Jan Schaafsma, the General Petroleum chemist. He said if Jan came from Honolulu originally there was probably some connection. When we informed him that we were personally related to the Dykes of Holland, he gave us exactly the kind of look we deserved. Anyway, Pete will soon be back in Los Angeles on his way to Sumatra, and we'll have to see if we can't get the Schaafsmas together.

Which ends another highly educational session. Did you know that dentists were the first to use portable drawworks?

W. W. Trout heads Lufkin Foundry

Walter W. Trout was elected president of the Lufkin Foundry and Machine Company, Lufkin, Texas, manufacturers of oil field pumping equipment, at the annual meeting of the board of directors in January. Trout, who has been with the company 23 years, beginning as a machinist in 1925, succeeds his father, the late W. C. Trout, who had headed the foundry since its start early in the century. Walter Trout has been vice president and general manager of the foundry, and since the death of his father in April, 1947, has been acting head of the giant Lufkin industry.

Walter W. Trout

Trout is a graduate of Purdue University and attended Rice Institute and the University of Texas.

W. D. Winston, Jr., who has been with the company 34 years, was elected to the board of directors, to fill the vacancy left by the death of W. C. Trout. All other officers and directors were reelected.

Vice presidents are J. H. Kurth, Jr., Houston; E. P. Trout, Lufkin; A. E. Cudlipp, Lufkin, and L. A. Little, Dallas. Winston was reelected secretary and E. H. Bounds was renamed treasurer.

The board of directors includes Walter Trout, J. H. Kurth, Jr., E. L. Kurth of Lufkin, Little, S. W. Henderson, Jr. of Lufkin, Eli Wiener of Dallas, Cudlipp, Jacques Wiener of Shreveport, and Winston.

John Tullis manager of sales

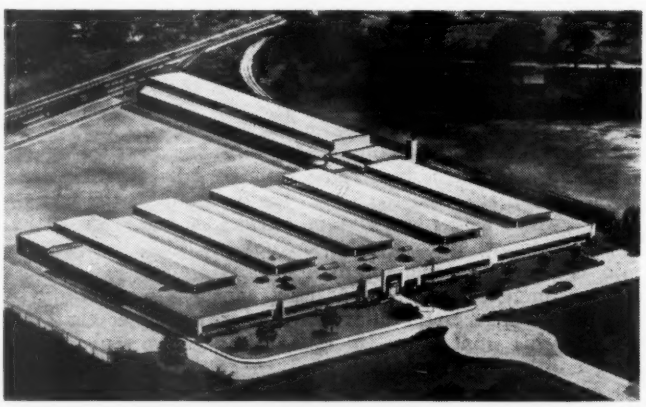
John L. Tullis has been made manager of sales of The J. B. Beaird Company, Inc., of Shreveport, Louisiana. The appointment was effective January 15.

Armstrong Bros. new offices and works

New general offices and works of Armstrong Bros. Tool Company situated in the Elston-Central Industrial District at 5200-5300 West Armstrong Avenue, Chicago, Illinois, are shown in the accompanying photograph.

Founded in 1890, Armstrong Bros. Tool Company has grown steadily until today the Armstrong catalog lists more than 6500 different tool items.

Now operating in this ultra-modern new plant—monitor type, one-story construction in light grey brick with stone trim and beautifully landscaped—Armstrong Bros. have more than 170,000 sq ft of manufacturing space.



Core Lab field laboratory

W. H. Davison, president of Core Laboratories, Inc., 2151 Fort Worth Avenue, Dallas, Texas, has announced that final inspection and testing has been completed on the company's newest portable core analysis field laboratory, believed to be the largest of its type in the world. Core Lab's fleet of active portable units, for years familiar trademarks in all major drilling and producing areas throughout the United States, now totals 22, in addition to seven large stationary laboratories in Dallas, Houston, Corpus Christi, Shreveport, Oklahoma City, Evansville, and Bakersfield.

W. H. Davison

Initial operation of the new laboratory, specifically designed and equipped to simultaneously analyze 60-ft cores indigenous to drilling in the Rocky Mountain area, will be from a semi-permanent location in the Rangely field, Colorado.

Planned, engineered, and constructed under the direction of John D. Wisenbaker, manager of operations, at a cost of approximately $10,000, the all-aluminum trailer-type lab meas-

John D. Wisenbaker inspects the portable laboratory.

Laboratory has all-aluminum corrosion and rust-proof construction.

ures over 28 ft in length and weighs 6000 lb. Cabinets, doors, and other fixtures are also of aluminum, making the entire unit completely corrosion and rust-proof. It is wired for 300 amp, lighted with fluorescent lamps, and insulated throughout with 2 in. of fiber glass.

Arrival of the lab from Dallas will be of special interest to Colorado operators who have been employing the diamond-head type core barrel in virtually all coring programs. Each run of the latter usually results in the taking of up to 60 ft of

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sub-surface samples from formations, heretofore extremely difficult to do. With nine engineers, under the supervision of James D. Harris, district engineer, offering continuous 24-hr service in the large laboratory, drilling, coring, core analysis, and well completion will be greatly facilitated throughout the entire area.

Rope sales department

R. G. LeTourneau, Inc., Peoria, Illinois, has created a wire rope sales department. With the advent of this new department LeTourneau will incorporate a full line of sizes, types, and construction of preformed and non-preformed wire rope under its trade name Tournarope.

Direction of the Tournarope sales will be under the supervision of W. H. Wilson, wire rope sales manager. A graduate of Washington and Jefferson College in 1938, Wilson received his master's degree in business administration at the Wharton Graduate School, University of Pennsylvania in 1940. Prior to

W. H. Wilson (left), M. R. Kahle, and A. J. Becker.

his affiliation with R. G. LeTourneau, Inc. in August of last year, he was employed by John A. Roebling's Sons Company, Trenton, New Jersey.

Assisting Wilson will be Michael R. Kahle and Alvin J. Becker, sales engineers. Kahle for eight years was employed by the Broderick and Bascom Rope Company, St. Louis, Missouri, as district sales representative in the coal and industrial fields.

Alvin J. Becker joined services with LeTourneau in 1937 in the production department. From there he rose to supervisor of stock control, assistant production manager, and production manager. He transferred to the sales division in July of last year.

Cooper-Bessemer executives promoted

The Cooper-Bessemer Corporation has announced the elevation of three of its sales executives to positions of vice president.

Those so honored, in recognition of their outstanding sales

B. L. Potter

A. A. Burrell

J. W. Reed

achievements and their many years of service, include J. W. Reed, the company's Atlantic Coast manager of gas engine and compressor division; A. A. Burrell, Southwestern district manager, with headquarters in Dallas, and B. L. Potter, Mid-Continent manager with headquarters at Tulsa, Oklahoma.

Spartan begins cementing operations

In January the first completed oil well cementing unit rolled out of the Houston plant of Spartan Tool and Service Company and immediately was driven to Victoria, Texas, to do its first oil well cementing job at a well. The well is owned by John Loftee of Houston and is being drilled by Lon H. Cron and Son Drilling Contractors of Houston. The cementing job was successfully completed using 525 sacks of cement. H. F. (Blackie) Clark, vice president in charge of field operations for Spartan, supervised the operation of the cementing unit. Wayne Dodson was the cementer and Leroy Shook represented the Spartan engineering department.

Although this is the first cementing unit and the first job by this new company, the men who organized the company have spent their business life time in the oil well cementing business. These men include C. P. Parsons, president, H. F. "Blackie" Clark, vice president in charge of field operations, and Turner Briggs, vice president in charge of sales. The other officer is William H. Quinette, secretary-treasurer. The company has grown from just an idea last July to 875 employees at present.

Spartan's initial capitalization is $3,500,000. Its main offices are 2101 Esperson Building, Houston, Texas, and the main plant is at 2101 Old Spanish Trail.

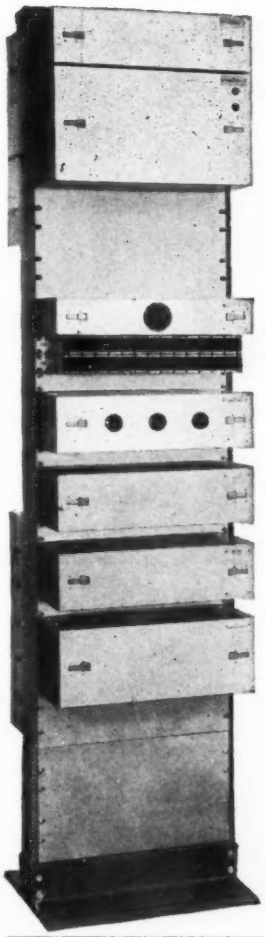
Two and one-half million dollars is being expended during the first six months for equipment, which will be assembled at the main plant.

C. P. Parsons, president, has been in the oil business for 29 years and is well known throughout the oil industry. He entered the oil business after World War I in which he served as a pilot in the Army Air Force. His original connection was with the Magnolia Petroleum Company where he remained until 1929, becoming district superintendent in charge of drilling and production in southern Oklahoma. He then went with Halliburton Oil Well Cementing Company, Duncan, Oklahoma, as chief field engineer and also served as a director of the company. From 1932 to 1935 he was manager of sales and from 1935 to 1946 he was vice president in charge of sales and vice president and sales consultant of Hughes Tool Company, Houston, Texas, and in May, 1947, resigned to devote his time to the organization of Spartan.

H. F. Clark, vice president, was associated with Halliburton Oil Well Cementing Company from 1926 to 1945, his last position being that of division superintendent in charge of operations in the Gulf Coast area. He then went into the oil well testing tool business and until the organization of Spartan was president and director of Perfo-Test, Inc. and vice president and director of Hunt-Clark Company.

Turner Briggs, vice president, joined Halliburton in 1933

Spartan's first cementing job, Victoria, Texas.



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SAN CARLOS, CALIFORNIA

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MERCURY SWITCHES

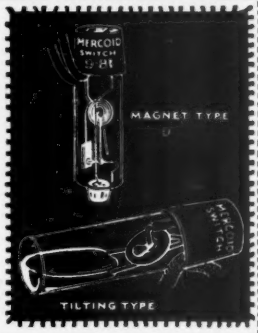
THE MOST IMPROVED TYPE IN MERCURY CONTACT SWITCH CONSTRUCTION. ●

Mercury switches bearing the registered trade mark name of "Mercoid" are not subject to open arcing, oxidation, corrosion, pitting or sticking of the contacting surfaces.

There are numerous applications where these switches have a definite advantage over the open contact type switches.

Mercoid switches are available to the trade in various designs, sizes and capacities.

Our engineers gladly offer their assistance in the adaptation of our switches to your switch problems.



MERCOID

SOLVES INDUSTRY'S AUTOMATIC CONTROL PROBLEMS

Designed to automatically regulate electrically operated equipment in accordance with changes in temperature, pressure, vacuum, fluid level or mechanical movement.

For further information see catalog No. 600

THE MERCOID CORPORATION

4227 West Belmont Avenue, Chicago 41, Illinois

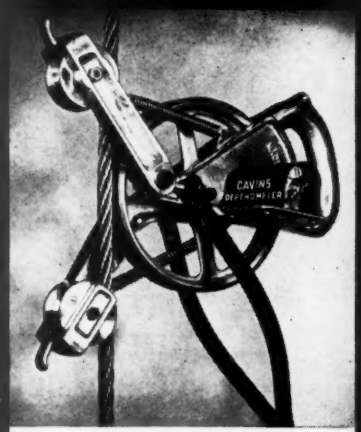
MANUFACTURERS OF AUTOMATIC CONTROLS FOR HEATING, AIR CONDITIONING, REFRIGERATION AND NUMEROUS INDUSTRIAL APPLICATIONS. ALSO MERCOID BRAND MERCURY SWITCHES.

Here's the Accurate Way to take Wire Line Measurements

Easy to use ●

Light and handy to carry ●

No more "Stringing-in" Guess Work ●



Gives you accurate depth ●

Direct reading ●

Pays for itself in a short time ●

Hundreds of Cavins Depthometers are in successful service giving their owners direct-reading, accurate well measurements. This strong, simple device comes in a handy carrying case (weighs only 17 pounds)—is put on the line in a few seconds, and tells you where bottom is quickly and dependably. —Write for folder to The Cavins Co., 2853 Cherry Ave., Long Beach 6, California.

THE CAVINS DEPTHOMETER

as a truck driver and became credit and sales manager for the Gulf Coast division. He left Halliburton in April, 1947, to become associated with Glenn McCarthy as president and director of Houston Foreign Trade Import Company and director of Houston Export Company.

W. H. Quinette, secretary-treasurer, has been engaged in accounting and tax matters for 25 years. For the last 20 years he was associated with the national accounting firm of Peat, Marwick, Mitchell and Company in their Tulsa, Denver, and Houston offices.

B. R. Thompson, who will handle export, graduated from Rice Institute (1937) with a degree in petroleum engineering. He worked for Halliburton on a cementing truck from 1938-1940; field engineer for Lone Star Cement Company, 1940-1942; combat pilot, 8th Air Force 1942-1945, completing 35 bombing missions over Germany for which he received numerous citations. Served as division sales manager in California for Halliburton 1945-1946.

In addition to oil well cementing, the company will operate a fleet of bulk cement trucks. The initial plan calls for 50 oil well cementing units and 37 bulk cementing trucks. In addition to oil well cementing the company is now operating the "Perfo-Tester," a combination gun perforator and casing testing device that was acquired through the purchase of Hunt-Clark Company several months ago. Perfo-testing stations are now maintained at Corpus Christi, Victoria, and Houston and an expansion program to other areas is now under way. Among the other devices that are in process of design and manufacture are formation testers, squeeze tools, and other accessories to be used in the servicing of wells.

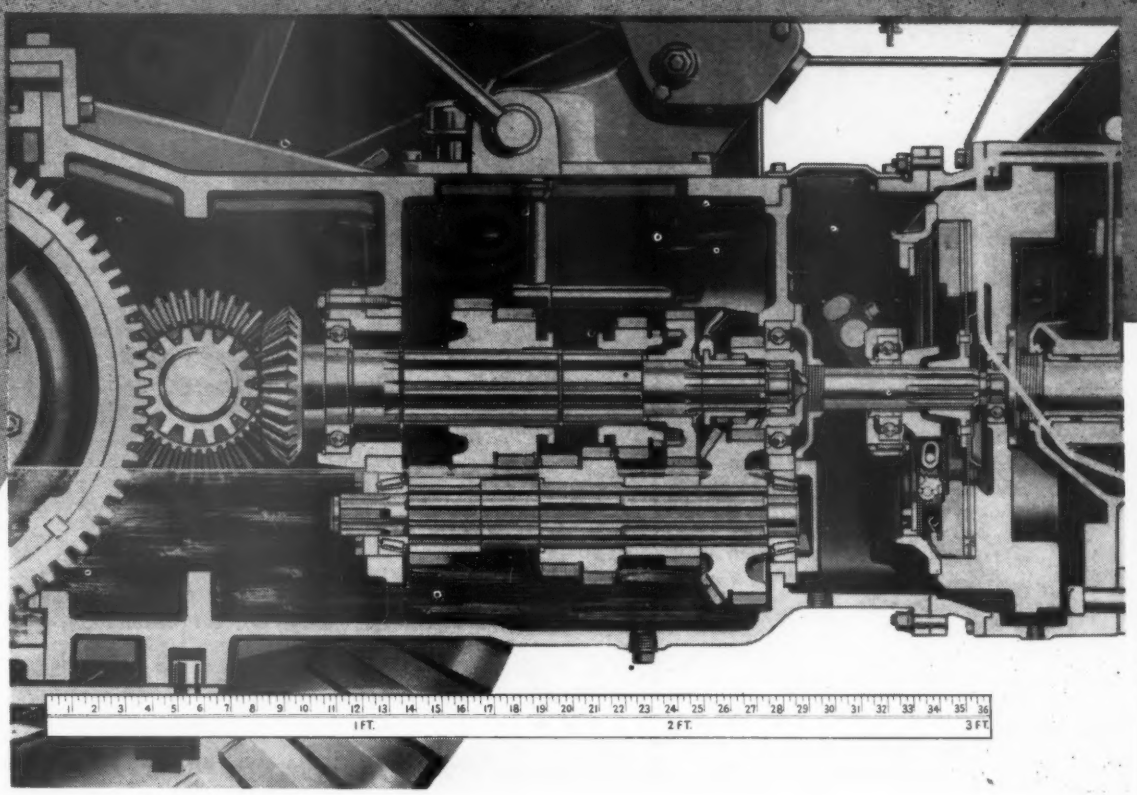
Receives public relations award

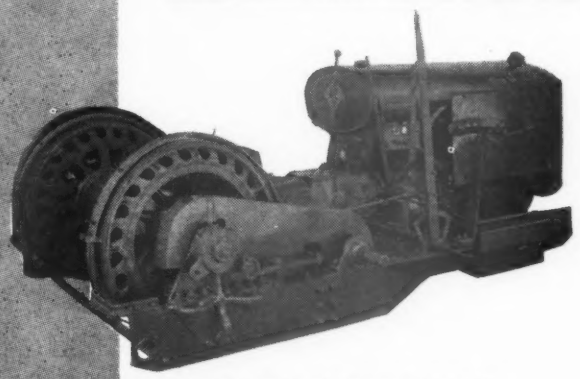
The Gulf-Southwest district of the Oil Industry Public Relations Committee received top recognition for industry public relations activity during 1947 in the annual awards of the Public Relations Institute of Texas, results of which were announced at the American Petroleum Institute's annual awards meeting. Fred F. Murray, chairman of the industry's committee in the Gulf-Southwest, comprising Texas, New Mexico, Louisiana, Arkansas, Mississippi, and Alabama, received a citation for outstanding achievement from Gerald Cullinan, president of the Texas Public Relations Association. Murray is president of the Oil Well Supply Company.

Gerald Cullinan (left), Paul Cain, and Fred Murray.

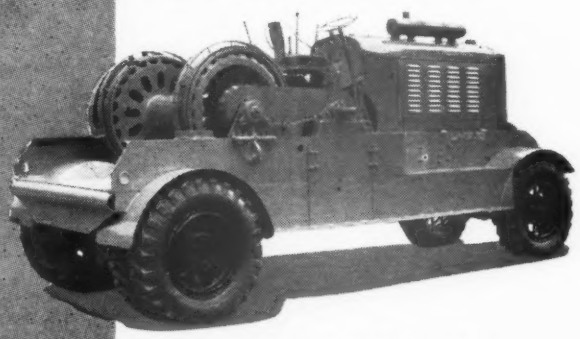
Co-recipients with Murray of the award were John P. Morgan, Sun Oil Company, committee vice president, and Paul Cain, Fred Eldean Organization, the industry's public relations counsel.

HEAVY DUTY TRANSMISSIONS





A-C MODEL E-563—36" Single Drum Skid Winch. Also available with 42" drum.



A-C MODEL L-844—42" Single Drum Tractor Type Well Servicing Unit. Also available with 52" drum.

The measure of usefulness of any oil well servicing unit is work. ***Unless the power of the engine is usable it is of little value.***

The heavy duty tractor type transmissions in Allis-Chalmers–Fred E. Cooper Pulling Units are equipped with heavy duty, deep groove ball and roller bearings throughout. The capacities of the components and the whole are greater than standard transmissions. They are designed and constructed especially for A-C oil well servicing units and are **NOT** available in other hoisting equipment.

A Cooper engineer will be glad to furnish detailed specifications.